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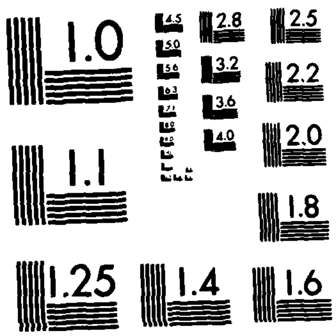

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AH-64 AUTOMATIC TEST EQUIPMENT REQUIREMENTS

Working Note ML213-1

November 1982

Frans Nauta

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PREFACE

Although this working note is dated November 1982, most of the information it reports was collected in the spring of 1982. It reflects test equipment requirements as of May 1982. At that time, the Army was planning to conduct follow-on testing of reliability, availability and maintainability of the MSM-105(V)1 during the summer of 1982 and to complete operational testing (OT III) in December 1982. Results of those tests are not reflected.

SUMMARY

The Army's new advanced helicopter, AH-64 relies on automatic test equipment (ATE) at aviation intermediate maintenance (AVIM) units for testing and diagnosis of faulty components removed from the aircraft. The Army is planning to provide one ATE station to each division and corps aviation brigade AVIM unit that supports the AH-64. Our independent analysis indicates that one ATE per AVIM may be sufficient only if the mean time between removal of AH-64 line replaceable units is 6 to 8 flying hours or greater, a figure that, though perhaps achievable, is twice that demonstrated so far in operational testing.

More importantly, we found it necessary to make assumptions about most characteristics of the AH-64 and ATE that are key to an ATE requirements computation; the Army does not have the data needed to make accurate estimates. While we believe our assumptions to be reasonable, they leave us with much uncertainty about the Army's ATE requirements. The Army cannot afford uncertainty about ATE support to the AH-64. The maintenance plan for the helicopter assumes that the ATE programmed for each echelon will be adequate to handle the workloads generated for that echelon. If it is not, repair turnaround times will become long, inventories of spares will be exhausted, and aircraft combat operational availability will plummet.

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1. INTRODUCTION

BACKGROUND

The AH-64 APACHE is the Army's new advanced attack helicopter. Like other modern, sophisticated weapon systems, its maintenance support relies on automated, computer-controlled diagnosis of system failures. The Fault Detection/Location System (FD/LS) on-board the helicopter identifies system failures and fault-isolates to the line replaceable unit (LRU). Automatic test equipment (ATE) is used at the intermediate and depot levels of maintenance to verify failure of the LRU and diagnose the cause.

Although the Air Force and Navy have over a decade of experience in the use of ATE, the Army's experience in its use is limited to commercial equipment installed at depots. The AH-64 will be one of the first major, Army systems requiring tactical deployment of ATE for its support. Tactically deployed ATE will be subject to utilization constraints that do not affect fixed, depot equipment; for example, frequent moves necessitated by changes in the tactical situation. The issue is whether the Army has adequately considered such constraints in determining the number of ATE stations it needs to support the AH-64. Before addressing the issue, some description of the AH-64's ATE and deployment plans is necessary.

ARMY AUTOMATIC TEST EQUIPMENT

The Army is committed to the AN/USM-410 as the standard ATE for general support and depot levels of maintenance. (The AN/USM-410 program history is described in Appendix B.) The USM-410 is composed of commercial, as opposed to militarized, equipment. Thirty-nine dismounted systems have been procured and installed at contractor sites for development of test program sets (TPS);

at Army depots (Tobyhanna and Sacramento) for TPS development and use; and at the Pirmasens Communications-Electronics Maintenance Center (PCMC) for operational use. The nomenclature for the van-mounted version, which is planned for general support units, is AN/MSM-105(V)1. A different version, consisting of the same AN/USM-410 core but augmented with test equipment peculiar to the AH-64, is designated AN/MSM-105(V)2.

The AN/MSM-105(V)2 is planned for deployment in two configurations. One, without the electronic repair facility, is for employment at divisional aviation intermediate maintenance (AVIM) units for use in repairing LRUs. The other, with the electronic repair facility, is for employment at corps AVIM units for use in repairing both LRUs and printed circuit boards.

ATE DEPLOYMENT

Initially, the U.S. Army Training and Doctrine Command sought to limit ATE use to corps AVIM. It later modified this position to permit ATE at divisional AVIM, but only for repair of LRU, not shop replaceable unit (SRU).[1] The Materiel Development and Readiness Command held that the ATE at divisional AVIM would be underutilized if limited only to LRU checkout and fault isolation. In September 1981, the Army Deput Chief of Staff for Logistics formally approved ATE in the divisional AVIM for LRU testing and repair, with the ATE at corps AVIM authorized for testing and repair of both LRU and SRU.

ARMY ESTIMATES OF ATE REQUIREMENTS

The Army has conducted a number of studies of the adequacy of planned ATE capacity to support AH-64 peacetime and wartime requirements. A Cost and Operational Effectiveness Analysis by the U.S. Army Logistics Center was completed in early 1974. The primary purpose of that study was to demonstrate the cost savings attainable from using ATE in lieu of the peculiar test sets

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[1] Most SRU are printed circuit boards.

and van-mounted hot mockups proposed by both contractors competing in the advanced attack helicopter (AAH) program. The analysis was based on a scenario with 12 AAH companies (18 unit-equipment (UE) each) flying 120 hours per aircraft per month. Preliminary engineering estimates of the reliability of 65 LRUs were obtained from the contractors. The analysis assumed that the built-in test equipment would perform in accordance with the requirement specified in the material need contract. The study determined that this scenario would generate a testing requirement of 5400 LRUs per month. It concluded that eight ATE stations would be required for LRU testing to support 216 AAH in wartime.

A second study conducted in 1976 by the Communications-Electronics Command (CECOM) concluded that a single ATE would be capable of supporting 218 AAH deployed in the European theater in peacetime as well as wartime conditions.[2] The study assumed that the fielded ATE station would only perform LRU checkout and repair, with overflow and printed circuit board checkout evacuated to continental United States (CONUS) depots.

A third study was an ATE workload analysis for the AAH conducted by RCA. This study was based on the workload generated by a complement of 83 selected LRUs. The study concluded that a single ATE performing LRU testing in support of 30 AAH would be utilized 31 percent of capacity by U.S. Army Europe (USAREUR), or 45 percent in CONUS in a peacetime flying scenario. A subsequent study conducted by the office of the PM, AAH analyzed the total workload (not just 83 LRUs) generated for LRU testing on the ATE. This study found that one ATE could cope with the workload generated by 30 AH-64, requiring somewhat less than a single-shift ATE operation (8 hours/day, 5 days/week) in

[2] G. Neuman, Computer-Controlled Automatic Test Equipment (CATE) Cost Effectiveness Study. Systems Analysis Office, ECOM, December 1976.

peacetime. The study suggested that in wartime (with six times the peacetime flying hours) the workload in excess of the divisional ATE (working double shift) could initially be evacuated to the backup corps ATE and would rapidly dissipate due to helicopter attrition losses.

The logistics support analysis process for the AH-64 program assumed adequate ATE, including LRU and SRU repair (when cost-effective) at divisional AVIM. The planned number of ATE stations was 23: 5 for training base, 12 for divisional and corps AVIM, and 6 for depot and factory support.

The current review of AH-64 fielding may change the numbers of ATE stations. Although no final decision has been made, we were informed by the AH-64 PM's office that the current plan for USAREUR is to field the AH-64 in the two corps aviation brigades only, three 18 UE attack helicopter battalions in each. Neither the divisions nor the armored cavalry regiments in USAREUR would, in peacetime, receive the AH-64 under this plan. As a result, while the original plan called for seven ATE's in USAREUR (one for each division and corps AVIM plus one float), the revised plan would field only three (one at each corps AVIM plus one float located at Pirmasens).

In sum, it appears that the Army plans to deploy one MSM-105(V)2 per corps aviation brigade and one per division aviation battalion, if the AH-64 is deployed in divisions.

ANALYSIS ASSUMPTIONS

In the next two chapters we assess, first, the ATE workloads that will be generated by the AH-64 and, second, the throughput capabilities of ATE at corps and division AVIM. Our goal is to find whether one MSM-105(V)2 per corps AVIM or division AVIM is sufficient to handle the workloads expected from peacetime and wartime operation of the AH-64. For purposes of the analysis, we assume a corps aviation brigade has 54 AH-64's and a division

aviation battalion has 36; the rationale for these assumptions is in Appendix A. The flying hour program we assume to be 20 hours per month peacetime, 70 hours per month sustained wartime, and 120 hours per month surge. Furthermore, we restrict our analysis to LRU workloads. Although the maintenance plan is to use the MSM-105(V)2 at corps level to test some SRU, there are insufficient data to support an SRU workload analysis.

2. ATE WORKLOAD ANALYSIS

ATE workload is a function of the number of LRUs to be tested and the time it takes for each test:

$$W = N \times T$$

where:

W = Annual ATE workload in hours
N = Number of LRU tested annually
T = Average test time per LRU

LRU TEST REQUIREMENTS

Figure 2-1 shows the numbers of LRUs to be tested (N), as a function of mean time between LRU removal (MTBR). The figure is based on the following assumptions:

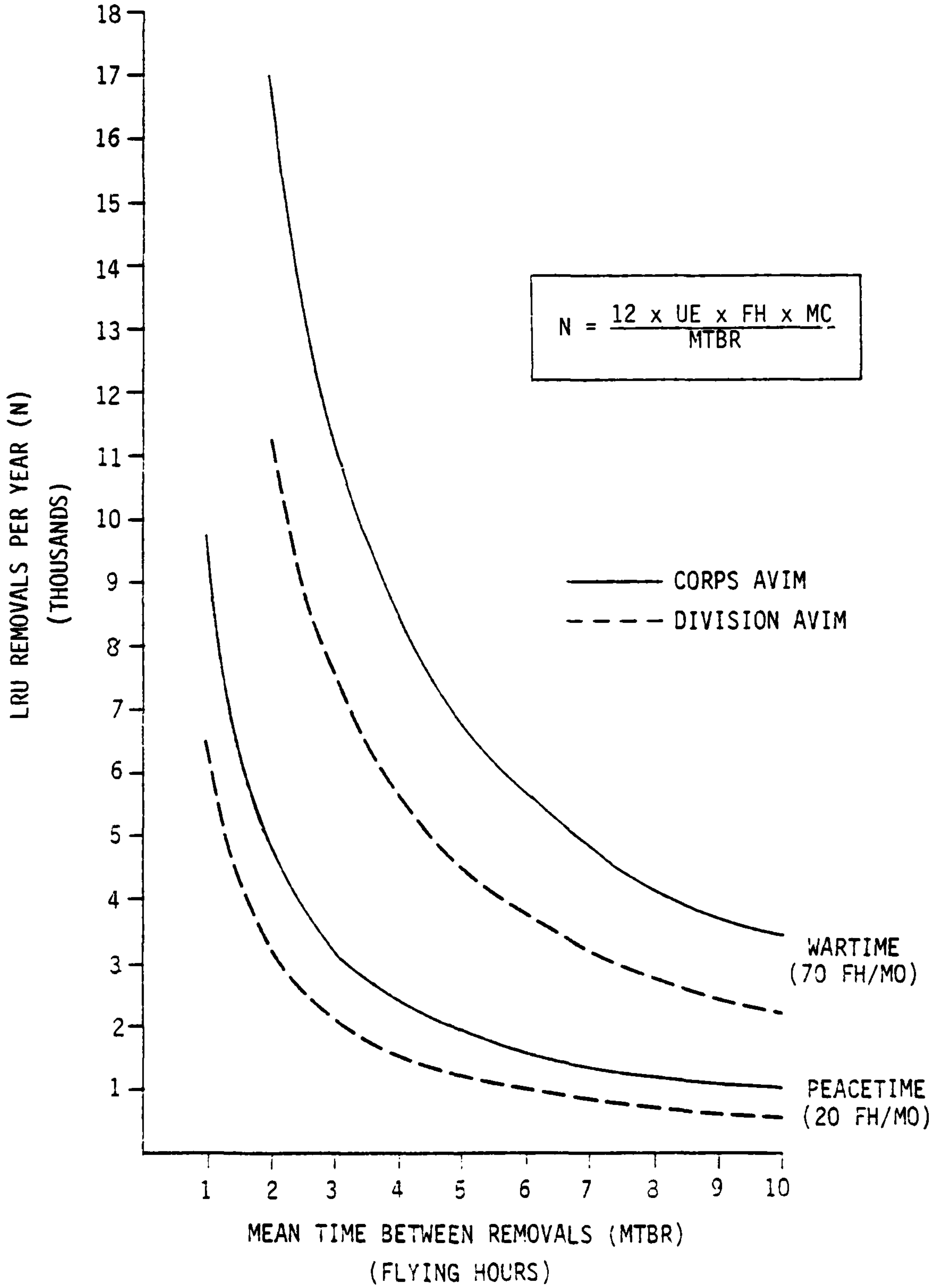
- An operational availability of 75 percent[1]
- no evidence of failure (NEOF) rate of 33 percent, which means that for each true malfunction, 1.5 LRUs, on the average, are removed from the aircraft

We have assumed that 33 percent of LRUs removed from aircraft will show NEOF. This is much higher than assumed by the Army for AH-64. The NEOF rate is a function of the performance of the built-in test equipment, which, for the AH-64, is the FD/LS. Both the materiel need and the development contracts specified that the FD/LS provide fault detection and isolation of 95 percent of all system failures, with a false alarm rate no greater than two percent. Test results show those specifications to be unrealistic.

Operational Test II (OT II) was conducted from June through August 1981, preceded by a Physical Teardown-Logistics Demonstration from January through

[1]The development program threshold, Integrated Program Summary (IPS) for the AH-64 Advanced Attack Helicopter (U), 29 October 1981.

FIGURE 2-1. NUMBERS OF LRU TO BE TESTED ANNUALLY



April. The OT II results are open to different interpretations due to: limited flight hours (400 hours for three aircraft), test aircraft not fully representative of the production configuration, incomplete FD/LS software, incomplete prototype ATE, and limited opportunity to assess either on-aircraft (FD/LS) or off-aircraft (ATE) diagnostics capability.

With regard to FD/LS, OT II results show the following:

- Number of failures which FD/LS is designed to detect: 150
- Number of correct indications: 110
- Number of indications without a failure: 14
- Number of failures which FD/LS is designed to fault-isolate: 81
- Number of those failures accurately fault-isolated: 62.

Because the specifications do not explicitly discriminate between failures that are and are not addressable by the FD/LS (though fully automated fault isolation of all LRUs was always implied), the test data can be assessed in different ways. About 76 of the 112 LRUs are addressed by FD/LS, with about 60 tied into the multiplex system. Subsystems not addressed (e.g., some avionics LRUs) have their own internal diagnostics, requiring "push-to-test". And many failure modes exist which the FD/LS is simply not designed to address (e.g., wiring). The important point is that aviation unit maintenance personnel will have no special test equipment for manual troubleshooting other than standard test, measurement and diagnostic equipment such as multi-meters.

The Operational Test Evaluation Agency interprets the above data as follows:

- Fraction of faults detected: 73 percent
- False alarm rate: 11 percent
- Fraction of faults isolated: 77 percent.

From the same data, however, one can derive a statistic suggesting that the fraction of faults automatically detected and correctly fault-isolated is 41 percent -- the number of failures accurately fault isolated (62) divided by

the number of failures which the FD/LS is designed to detect (150). In view of the OT II experience, a decision-coordinating paper goal of 65 percent automatic fault isolation has been proposed for FD/LS at maturity.

TEST PROGRAM EXECUTION TIME

A test program has essentially three phases: a survey or screen test which checks that the specific test equipments to be used during this test are operational; a functional test (go/no-go chain) which determines whether the unit under test performs in accordance with design specifications and tolerances; and a diagnostic test which isolates a failure to one or more removable items (modules or boards for an LRU; components or piece parts for a module). The diagnostic test is normally entered automatically when the functional test determines presence of failure; most TPSs have multiple entry points for the diagnostic test. The same TPS used for fault detection/isolation is used after repair of the LRU or module for an end-to-end quality assurance check (functional test).

The execution or ATE run time for a test program varies widely and depends on the complexity of the unit under test and its design for testability. For complex items with more than 128 test points (the number of pins which the programmable interface unit of the USM-410 can individually measure or stimulate under program control), the test must be interrupted to recable the required interconnection device and then restarted.

We received a complete list of LRU TPSs currently planned by PM, AH-64. A total of 100 LRU TPSs is planned, 78 of which will be fielded at AVIM test facilities. The remaining 22 LRUs are "potted" items which cannot be repaired in the field; they either are discarded or returned to depot level for repair. A total of 41 of the 78 TPSs have been delivered to date.

About 295 TPSs are planned for AH-64 SRUs (PCBs and modules), of which about 100 will be fielded at the Corps AVIM level. Only a few have been

delivered to date. The schedule calls for AVIM TPS completion by mid-1984, with depot-level TPS completed by the end of 1986. No specific data are available on SRU TPSs.

Our original intent was to construct a failure-frequency-weighted average TPS run time for AH-64 LRUs, combining the data from Appendix D with reliability data of the LRUs involved. We have not received the required reliability data from the PM, AH-64 in time for this report. As a result, we have made the following assumptions:

- The 78 different LRUs tested at AVIM have an equal probability of not being faulty.

- Only 10 percent of LRU failures occur in any one of the 22 "potted" items undergoing a functional check (go/no-go) only. The average test time ranges from 2 to 25 minutes (exluding hookup and disconnect) with a mean of 10 minutes.

- Of the 90 percent of failed LRUs, 75 percent require one diagnostic and, after repair, one functional test; 25 percent entail fault-isolation problems requring two diagnostic tests and one functional test. The average diagnostic time ranges from 7 to 150 minutes with a mean of 50 minutes. The average functional test requires 35 minutes.

Those assumptions lead to the following calculations of LRU test times:

$$\text{TEST TIME FOR FAILED LRU} = \underbrace{20\text{ min.}}_{\text{Hookup and Disconnect}} + .1\underbrace{(10\text{ min.})}_{\text{"Potted" Items}} + .9[.75\underbrace{(85\text{ min.})}_{\text{1 Diagnostic and 1 Functional Test}} + .25\underbrace{(135\text{ min.})}_{\text{2 Diagnostic and 1 Functional Test}}]$$

$$= 108.75 \text{ minutes} = 1.8 \text{ hours}$$

$$\text{TEST TIME FOR NEOF LRU} = \underbrace{20\text{ min.}}_{\text{Hookup and Disconnect}} + \underbrace{35\text{ min.}}_{\text{Functional Test}} = 55 \text{ minute} = .9 \text{ hours}$$

WORKLOAD

The result of multiplying the numbers of LRU to be tested annually by the average test time per LRU is the annual workload in hours. That workload, as a function of the mean time between LRU removals, is shown in Figure 2-2.

Figure 2-2 depicts workload as a function of LRU removal rate because mean time between removals (MTBR) is the greatest uncertainty in the workload calculation. Table 2-1 shows estimates of MTBR derived from three sources of AH-64 reliability data. The estimates range from a low of 3.2 flying hours demonstrated during OT II in 1981 to a high of 9.8 hours estimated by RCA for the AH-64 Program Manager in 1982.

Since workload is proportional to the inverse of MTBR, the workload implied by the OT II results in triple that implied by RCA's reliability estimates. Only by thoroughly testing the helicopter in an operational environment or carefully monitoring field operations will the Army discover the true MTBR and be able to confidently calculate ATE workloads.

We now turn our attention to throughput capability of the ATE.

FIGURE 2-2. ANNUAL ATE WORKLOAD

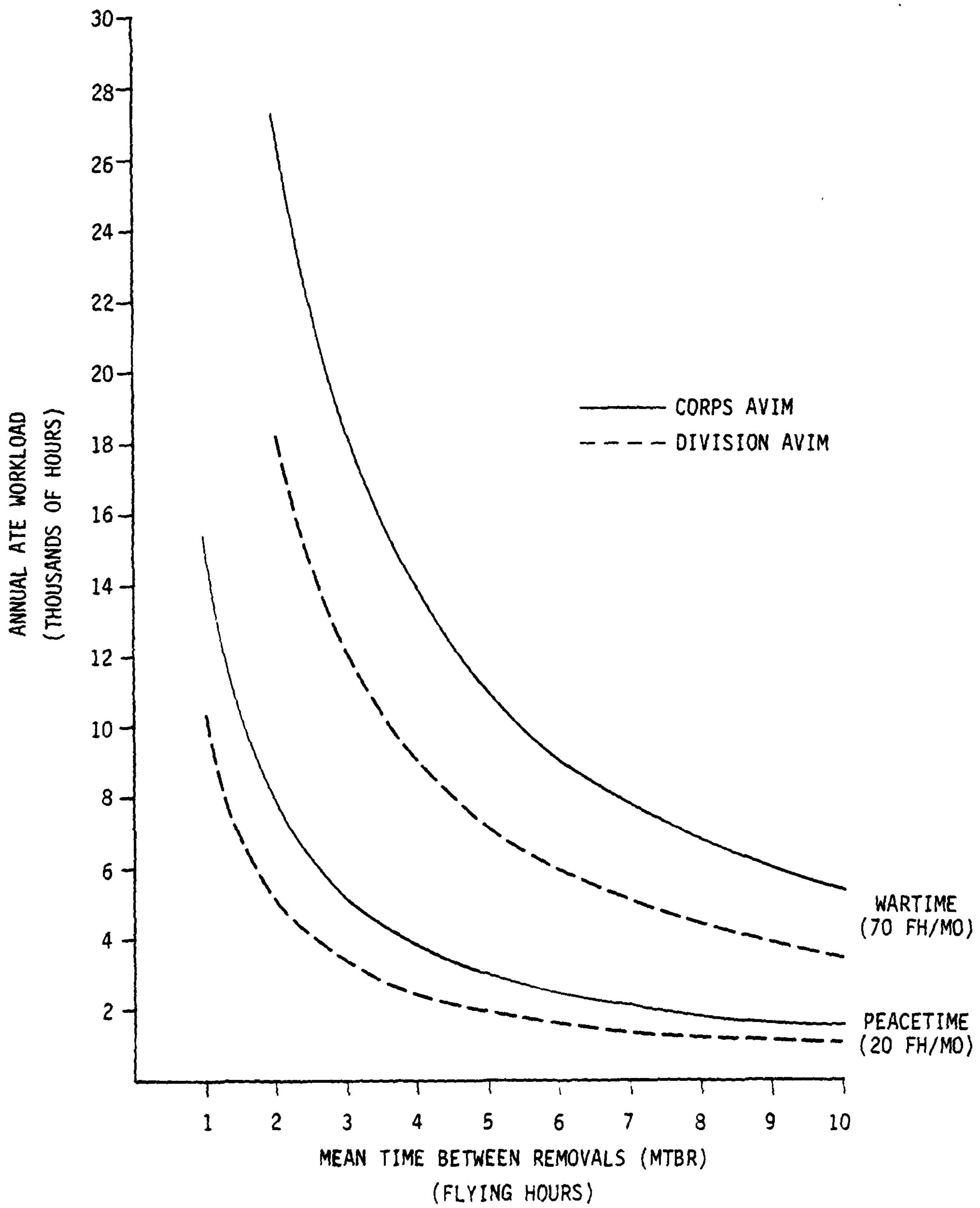


TABLE 2-1. ESTIMATES OF MTBR

DATA SOURCE	COMPUTATION
1 COEA, U.S. Army Logistics Center, 1974	Data: UE = 216, MC = 0.85, FH = 120, K = 0, N = 5400 (Data excluded TADS/PNVS LRUs) Compute: $\text{MTBR} = \frac{216 \times 120 \times 0.85}{5400} = 4.1$
2 Workload Analysis, RCA, 1981 (updated and reported to LMI by AH-64 PM office, 13 May 1982)	Data: RR(TADS/PNVS) = 0.0173[1] RR(AH-64 other) = 0.0850 (Both rates include 33% faults removals and correspond to MTBF values halfway between OT II results and maturity goals.) Compute: RR(AH-64 total) = 0.1023 MTBR = 1/RR = 9.8
3 OT II, 1981	Data: 124 BIT symptom indications in 400 aircraft operating hours Compute: $\text{MTBR} = \frac{400}{124} = 3.2$
Where	N = number of LRU removals per month (Fig. 2-1) MTBR = mean time between LRU removal (Fig. 2-1) FH = flying hours per aircraft per month MC = mission capable rate RR = removal rate = LRUs removed per UE per FH UE = unit equipment (aircraft) K = false removal rate = percent of RR with NEOF $\text{MTBF} = \frac{1}{1-K} \times \text{MTBR}$

[1]The TADS/PNVS Management Office advises that, for planning purposes, one should assume operating hours equal to flying hours.

3. THROUGHPUT CAPABILITY

The throughput capability of an ATE station is constrained by (1) the operational availability of the ATE system itself and (2) the availability of operator personnel. In this chapter, we examine both, for wartime and peacetime operations.

ATE SYSTEM AVAILABILITY

Operational availability is a function of the reliability and maintainability of the system. Since there is little information about the reliability and maintainability of the MSM-105(V)2, we start with assessments of the MSM-105(V)1 and other electronic equipment and infer reliability and maintainability characteristics of the MSM-105(V)2. From these characteristics, we calculate the operational availability of the MSM-105(V)2.

Reliability

The requirements document for the MSM-105(V)1 stipulates a minimum acceptable value of 75 hours MTBF. (Earlier documents on the USM-410 program identified higher thresholds and goals (250 and 500 hours, respectively).) Previous operational testing indicated a system reliability of 45 hours (OT I, 1978). The most recent test results (DT III, 1981) show a "mission MTBF" of approximately 14 hours if problems with the microwave rack are discounted. (The microwave rack was down most of the time. It was a prototype piece of test equipment independently developed by RCA, which will be totally redesigned.) The term "mission MTBF" includes failures attributable to factors other than hardware reliability (software errors, operator errors, etc.). Hardware failures cited by the Test and Evaluation Command include air conditioner failures and failures of the programmable interface unit, primarily the

"dual universal test point" boards in the programmable interface unit. Some of the latter problems, however, may be attributed to harsh treatment of the system during the test, which was not representative of the planned operational environment at a general support unit in the corps rear area. DT III was not designed to provide an estimate of system reliability; this objective is planned for follow-on tests in 1982. In the meantime, the consensus is that system MTBF will be well below the required 75 hours unless a major reliability growth program is undertaken.

We project that the achieved reliability of the USM-410 (the core of the MSM-105(V)1 and MSM-105(V)2 in the planned operational environment will be an MTBF between 40 and 60 operating hours, with non-mission-essential corrective maintenance required every 20 or 30 hours. We base this projection on the following observations and analogies:

USM-410 Depot Installations. Empirical data on the reliability of USM-410 systems dismounted at fixed plant installations show a range from 70 hours (lowest figure for three systems installed at Tobyhanna Army Depot) to 330 hours (highest figure for two systems installed at GTE Sylvania) with a composite, weighted average of 101 hours for all 39 systems currently installed.

Air Force ATE. The F-15 avionics intermediate shop (AIS) test equipment has an MTBF of 34 hours. This ATE, however, is much more complex than the USM-410: the number of parts is about 220,000 vice 15,000 for the USM-410, and the cost is about eight times that of the USM-410. The F-16 AIS, while less complex than the F-15 AIS, shows a mean time between corrective maintenance actions of only 4.59 to 6.29 hours (source: Air Force Test and Evaluation Command's Follow-on Test and Evaluation Study on four AIS stations, prototype hardware, conducted from January 1979 June 1980).

Operational Environment Factor. Surveys of electronic systems reported in the literature suggest that the operational environment factor responsible for reducing an MTBF demonstrated in the laboratory to a lower mean time between corrective maintenance experienced in the field typically ranges from 2.5 to 5.0 for ground electronics, with a not insignificant number of cases showing an even greater difference between demonstrated and actual reliability. That means that the 13 hour "mission MTBF" demonstrated in DT III could result in an MTBF of only 3 to 6 hours in the operational environment.

Tactical Systems. There are many examples of tactical electronics systems of higher complexity than the USM-410 (based on parts counts and cost) having a relatively high reliability. The AN/TSQ-73 Missile Minder, a command and control system for nondivisional high and medium air defense units is one good example. This system is housed in a single van smaller than the MSM-105(V)1 (15 feet, 4 inches long instead of 35 feet but with the same 10,000 lb. capacity). The system is inherently more complex than the USM-410 based on number of replaceable modules: 4,000 modules (primarily printed circuit boards) of 187 different types compared to about 600 modules of 275 different types. The mission reliability of the TSQ-73 in the battalion configuration is 280 hours MTBF, with a mean time between corrective maintenance of 145 hours. The difference between the USM-410 and the TSQ-73, of course, is that the latter is militarized, making it much less susceptible to failure in a tactical environment.

Mission vs. Hardware Reliability. Reliability assessment of the USM-410 is further obscured by the fact that several items may be "down" without affecting execution of a specific TPS. Most TPSs do not require all the test elements of the USM-410. Thus, in reality, the system possesses a

range of reliabilities depending on the TPSs being run. In other words, the ATE mission reliability would be higher than any measured MTBF. On the other hand, mission reliability would be affected by ATE operator errors and software problems. Since we have no data to the contrary, we assume that these effects counteract each other. Thus, we assume that ATE mission reliability will equate to MTBF.

With the reliability of the USM-410 core assessed at an MTBF of 40 to 60 operating hours in the field environment, the question is how the augmentation test equipment in the MSM-105(V)2 configuration would affect ATE system reliability. OT II of the AH-64 did not assess reliability of the prototype ATE used in the test. The prototype ATE did not include the Martin Marietta electro-optical augmentation equipment nor the motion subsystem. The Army plans to test the complete ATE during calendar year 1984, including physical teardown-logistics demonstration, follow-on operational testing and field demonstration test and experimentation of the first unit equipped at Fort Hood.

The only relevant information available is that the electro-optical augmentation equipment contract with Martin Marietta specifies a reliability requirement of 250 operating hours. In contrast, the contract with Hughes for the other augmentation equipment did not include any reliability requirements. The Martin Marietta equipment can be operated with much of the USM-410 core equipment "down." Moreover, based on the mix of LRUs flowing into the test station, the electro-optical test equipment would be used about 25 percent of the time the ATE is operated.

At the present time, we can only speculate about the reliability of the MSM-105(V)2. An estimate is needed, however, to assess throughput capacity. For the purposes of this study, we assume the USM-410 core with

Hughes augmentation equipment will have an MTBF of 50 hours, and the electro-optical test equipment an MTBF of 250 hours. With the assumptions of near independence and differential utilization, the mission reliability of the total ATE would be 100 hours.

Maintainability

MSM-105(V)1. Performance of the self-test diagnostics is important to the maintainability of the ATE. DT III of the MSM-105(V)1 was conducted in two phases: a June-September 1980 test of environmental and transportability issues, and an April-September 1981 test of reliability, maintainability, system performance, electromagnetic interference, and TPS transportability. While DT III was not designed to provide a rigorous assessment of self-test performance, it was the first field test of this new software. Test results revealed serious shortcomings in maintainability caused by inability of the system self-test to diagnose faults accurately and consistently, and by inadequate technical manuals. (This assessment was reported by the U.S. Army Logistics Center observers at DT III; we have not reviewed the formal DT III Test Report by the Test and Evaluation Command which was scheduled for release in March 1982 but was unavailable to us in time for this report.) Most of the required corrective maintenance during the test was performed by contractor personnel.

To what extent the diagnostic software shortcomings of the MSM-105(V)1 indicated by DT III will be corrected is difficult to say. There is no reason to believe the required level of 90 percent fault isolation cannot be attained. Practically, it seems doubtful that such a level will be achieved. One reason is that pressures to field new equipment invariably override needs for testing and maturation of self-test diagnostics software. Even if a thorough failure mode effects and criticality analysis could be done

for built-in test or self-test software, the time required to debug and validate this software is normally in excess of what is allotted for this purpose in the typical program schedule. In the absence of a complete failure mode effects and criticality analysis (a prime candidate for being cut when a program is over cost or schedule), the required testing time is even longer. A second reason is the Army's lack of a strong, coordinated "get-well" program once new equipment is fielded. At least, this has been the experience to date. The impact of self-test software shortfalls may not be recognized, or development and implementation of needed improvements may receive too low a priority for funding. This also applies to tactical end items as well as to lower priority support equipment such as ATE.

For example, although the TSQ-73 was fielded in 1979 in USAREUR, the system's self-test diagnostics software has serious problems which have never been corrected. The fault catalog, which lists the suspect boards associated with each fault code displayed by the self-test, is deficient; for many failure symptoms, the actual culprit is not included in the fault catalog. This renders the fault catalog of little practical use. Proper use of the test set (required to isolate the fault within an ambiguity group to a single board) requires more experience and skill than is possessed by the operator/maintainer. Furthermore, portions of the system were never production engineered; e.g., the remote interface unit, which interfaces with acquisition radars and IFF,[1] is prototype hardware with little documentation. The consequence of these shortcomings is that many of the system failures are beyond the capability of the operator/maintainer crew and require a warrant officer or on-site contractor technician. Another example is the TACFIRE fire direction center, a van-mounted (but dismountable) command and control system for

[1]Identification friend or foe systems.

field artillery. Its self-test diagnostic software isolates only 60 percent of system failures. This shortfall caused a change in maintenance concept. Instead of the operator/maintainer removing or replacing single boards, a direct support contact team replaces entire assemblies or racks, and then repairs the assemblies in a divisional shop using a "hot mockup" type of test set for fault isolation.

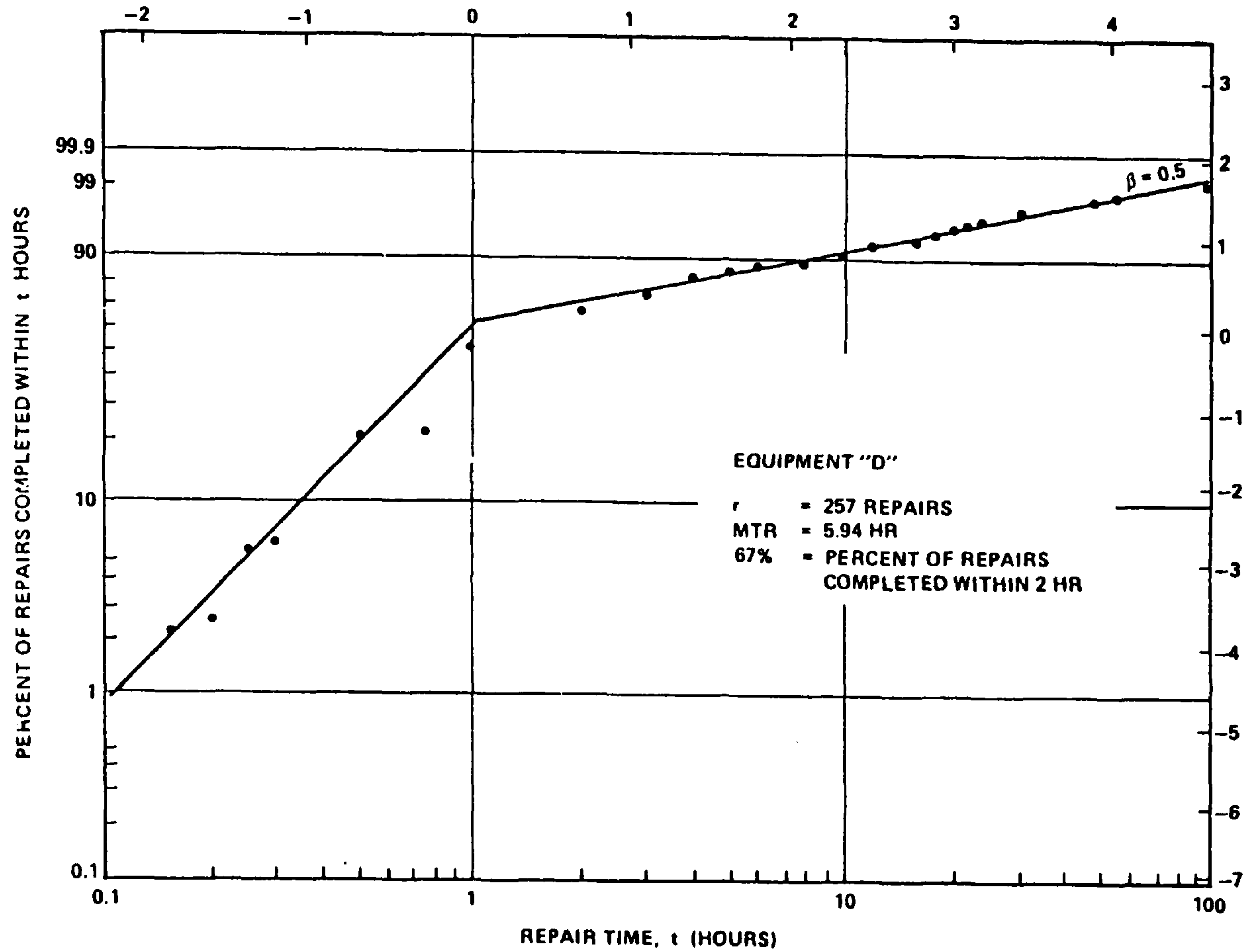
We developed our independent quantitative estimates of maintainability of the MSM-105(V)2 using empirical data available for other systems. Test data for the F-16 AIS station indicate a mean time to repair of two to three-and-a-half hours, but we have no information as to who did the repairs. For the F-15 AIS, Air Force data indicate that about 30 percent of the personnel associated with ATE operation and maintenance consist of civilian contractor technicians and Air Force Engineering Technical Services technicians. Most of the corrective maintenance on site is done by contractor personnel. It is also reported that about 25 percent of the original selftest diagnostics were erroneous--a figure which does not include additional wrong indications caused by failures that the self-test was not designed to fault-isolate (e.g., bent pins, wiring, stuck relays, dirty connectors, wrong cabling of ICDs). The overall result was that 40 percent of the LRUs that were pulled off the ATE in the belief they were faulty, actually showed no failure when tested at the depot level--in Air Force terms, a 40 percent retest okay rate. Recent software improvements, however, are reported to have driven this retest okay rate down to 15 percent.

Another analogy consists of repair time distributions for tactical, electronic end items. Previous research on maintainability of electronic equipment fielded in the late 1960s/early 1970s indicated that the majority (65 to 80 percent) of failures are diagnosed and repaired within a short time

(two hours), but that the remaining failures require a much longer time to repair due to diagnostic and fault-isolation problems (see Figure 3-1). System failures fall into two categories: those addressed by the system's design for maintainability (built-in test, troubleshooting aids, etc.) and those that escape these features. The latter category is characterized by a low slope of the cumulative frequency distribution of repair time, indicating a decreasing diagnostic efficiency (probability of fault isolation per time interval) with time. The graph of repair time distribution often reveals the existence of two distinct regions. Other investigators have hypothesized the existence of three regions: one comprising faults which are automatically fault-isolated through built-in test; a second region associated with semi-automated fault isolation, requiring some proceduralized troubleshooting either with machine prompting or using a technical manual; and a third region, where the maintainer has no proceduralized aids and must rely on schematics, experience and knowledge to isolate a failure to an LRU.

In view of the data available, we project that the self-test for the USM-410 core will not exceed a level of 70 percent automatic fault isolation to a group of five or fewer LRUs. Manual fault isolation within the group may require considerable time. The applicable technical manual suggests that the ATE operator replace all suspected LRUs whenever his work is backlogged instead of removing and replacing each LRU one at a time and verifying system operaton. Although a block replacement approach may not be supportable by available spares stockage, we assume that the mean repair time (including diagnostics and system verification) for 70 percent of the failures will be two hours. We also assume that the system maintainer will be able to fault-isolate and repair an additional 20 percent, using his knowledge and experience, system schematics and manual test equipment, with an average

FIGURE 3-1. CUMULATIVE FREQUENCY DISTRIBUTION (CFD) OF REPAIR TIME FOR ELECTRONIC EQUIPMENT PLOTTED ON WEIBULL PROBABILITY PAPER



Source: "Diagnostic Behavior, System Complexity, and Repair Time: A Predictive Theory," by Joseph G. Wohl, MITRE/Bedford M80-00008, April 1980.

repair time of eight hours. The remaining 10 percent is assumed to require non-organic assistance with an administrative delay time of twelve hours and repair time of four hours.

Because spare parts are not all stored on site with the ATE, we also must estimate the logistics delay time associated with a repair action. The ERPSL[2] items are distributed among on-site storage (56 percent), supply support activity (22 percent) and centralized corps GS (22 percent). However, taking failure frequency into account, we assume that 70 percent of the needed replacement parts are stored on site, with 20 percent at supply support activities and 10 percent at corps general support. The MSM-105 table of organization and equipment (TOE) does not include a supply clerk or parts "runner"; thus, we assume that an average delay of two hours is encountered in getting a needed part from on-site storage. For supply from supply support activities and GS, we are assuming average delays of 12 and 24 hours, respective, which are optimistic estimates for USAREUR.

In summary, our maintainability estimates for the M-105(V)1 electronic test facility are as follows:

- MTTR = (0.7 x 2) + (0.2 x 8) + (0.1 x 4) = 3.4 hours
- Administrative delay time = (0.1 x 12) = 1.2 hours
- Logistics delay time = (0.7 x 2) + (0.2 x 12) + (0.1 x 24) = 6.2 hours
- Mean down time per failure = 10.8 hours

This estimate pertains exclusively to the electronics test equipment. Not included are support problems with associated generators and air conditioners, support of which is extremely weak in USAREUR. This probably explains some of the support problems of a system like the TSQ-73, which has a mean down time

[2] Essential Repair Parts Stockage List.

of 296 hours. In other words, we believe our estimate is optimistic; it is based on fully funded ERPSL and availability of generators and air conditioners.

MSM-105(V)2. Information on the augmentation test equipment is too limited at the present time to permit any reasonable assessment of maintainability. The maintenance concept and self-test requirements are still under review. The intent is to develop self-test software covering the several hundred replaceable modules (including some major vendor items). Spare parts stockage data are unavailable. In the absence of any specific data, we assume that the mean down time per failure will be similar to that of the MSM-105(V)1, amounting to 11 hours per failure.

Operational Availability

MSM-105(V)1. The requirements document specifies an operational availability (A_o) for the MSM-105(V)1 of 85 percent. The PM, TMDS computes available ATE test hours as follows:

- Peacetime. Single shift operation of eight hours per day with one hour required for preventive maintenance. Net available test hours: 0.85 x 7 x 5 x 52 = 1547 hours/year/station.
- Wartime. Double shift operation of twelve hours per shift with an allowance of one hour preventive maintenance per day and two and a half hours for logistics delays and operator fatigue. Net available test hours: 0.85 x 20.5 x 7 x 52 = 6342 hours/year/station.

Our assessment of the reliability and maintainability of the system suggests that an availability of 85 percent is supportable under the assumed availability of supply support, power generators and environmental control:

$$A_o = \frac{MTBF}{MTBF+MDT} = \frac{60}{70.8} = 84.7 \text{ percent,}$$

where MDT = mean down time.

However, this does not include the effect of mobility on availability. According to Army doctrine, the ATE employed in the Corps area will be moved

once a week. The extent of mobility actually required in wartime is, of course, dependent on the specific scenario. The average down time of the system due to movement under normal climatic conditions may be estimated at ten hours (one hour teardown, five hours per move of 60 kilometers, one hour setup, two hours warm-up, and one hour system turn-on and checkout). Under extreme temperature conditions, this down time may be longer because the system is without power for about seven hours; e.g., with an ambient temperature below 0°F, the temperature in the van after seven hours may be around 0°F, requiring a warm-up time of at least four hours.

In wartime, MSM-105(V)1 would not be moved by itself, but as a detachment to a light equipment maintenance company or as part of a GS maintenance support battalion under the revised general support concept. These larger units are only five to ten percent mobile; their movement over a distance of 60 kilometers is estimated to require 17-29 hours per move in lost productive time. This implies a loss of 21 percent of productive capacity, given one move per week (source: Army Logistics 1981 Study, August 1981).

Assuming the MSM-105(V)1 has an MTBF of 60 hours and an MDT of 10.8 hours, and looses 18 hours production time per week during moves, the system would be available 6135 hours per year during wartime. In peacetime, there are no moves, but the system is only operational eight hours a day, five days a week, so the available time is only 1500 hours per year. (See Table 3-1.)

TABLE 3-1. OPERATIONAL AVAILABILITY OF MSM-105(V)1

ITEM	PEACETIME	WARTIME
Gross annual hours	8 x 5 x 52 = 2080	24 x 7 x 52 = 8736
Mobility down time	0	52 x 18 = 936
Net annual hours	2080	7800
Daily preventive maintenance[1]	260 days @ 1.0 = 260	325 days @ 1.0 = 325
Down time for repairs	30 failures @ 10.8 = 320	124 failures @ 10.8 = 1340

[1]Preventive maintenance on days the system is moved is included in mobility down time.

MSM-105(V)2. A similar computation can be made for the MSM-105(V)2. The difference is that this system is planned for employment both at divisional and corps AVIM. At the outset of war, USAREUR plans to move Corps AVIM forward and divisional AVIM to the rear with a shorter distance between the two than in peacetime. Corps AVIM is more mobile than the conventional GS maintenance unit; its mobility is about 30 percent (vice 10 percent) so that the down time associated with a move will be less than the 18 hours assumed for the MSM-105(V)1. Similarly, divisional AVIM is more mobile than corps or general support (about 50 percent) but is by doctrine supposed to move twice a week in wartime. Table 3-2 shows that in divisional AVIM the MSM-105(V)2 would be available approximately 1622 hours per year in peacetime and 6383 hours per year in wartime. At the Corps AVIM, the wartime availability would increase to 6788 hours because of fewer moves. In the absence of any data, the figures shown in Table 3-2 are only rough estimates and should be interpreted with caution.

TABLE 3-2. OPERATIONAL AVAILABILITY OF MSM-105(V)2

DIVISIONAL AVIM	PEACETIME	WARTIME
Gross annual hours	8 x 5 x 52 = 2080	24 x 7 x 52 = 8736
Mobility down time	0	104 x 12 = 1248
Net annual hours	2080	7488
Daily preventive maintenance	260 x 1.0 = 260	313 x 1.0 = 313
Down time for repairs	18 x 11.0 = 198	72 x 11.0 = 792
System available time	1622	6383

CORPS AVIM	PEACETIME	WARTIME
Gross annual hours	2080	8736
Mobility down time	0	52 x 15 = 780
Net annual hours	2080	7956
Daily preventive maintenance	260	332
Down time for repairs	198	836
System available time	1622	6788

ATE OPERATOR AVAILABILITY

Peacetime

In 1980,[3] LMI reported that the productive utilization of direct support maintenance personnel is about 1100 hours per year in peacetime, even if there is no shortage of work. That figure is confirmed by a USAREUR Aviation Special Task Force study in early 1981 that concluded that the productive hours for aircraft maintenance personnel are about 20 per week. (See Appendix E.)

Since plans are to use single-shift manning for the MSM-105(V)2 during peacetime, operator availability will be about two-thirds the 1622 hours availability estimated for the ATE.

Wartime

The Army's manpower authorization criteria (MACRIT)(AR 570-2) sets standards for calculating wartime manning of tactical units. For Category II maintenance units, which includes the direct and general support units which will use the MSM-105(V)2, manpower authorizations are to be based on 2700 productive manhours per man per year. This figure is based on a 12-hour workday (4280 hours in a year) minus allowances for duty diversions (1050 hours) and movement (630 hours). Assuming the Army uses two-shift manning during wartime, operator personnel would be available 5400 hours per year, about 15 percent less than the system available time at divisional AVIM and 20 percent less than at Corps AVIM.

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[3]LMI Interim Report ML904, Air Defense Systems, May 1980.

4. CONCLUSIONS

ATE WORKLOAD vs. CAPACITY

Is one MSM-105(V)2 per corps aviation brigade or division aviation battalion sufficient to handle the expected AH-64 workload? The answer depends on the LRU removal rate of the AH-64. In Figure 4-1, the wartime and peacetime system availabilities are overlayed on the graphs of ATE Workload by MTBR. At the division level (division AVIM), one MSM-105(V)2 should be sufficient in both peacetime and wartime if the MTBR for the AH-64 is six flying hours or better. Although six hours MTBR is almost twice the MTBR demonstrated during OT II, it probably is achievable. However, if the MTBR is no better than six hours, during peacetime ATE utilization may be as much as one-third less than its potential because no operator personnel are available.

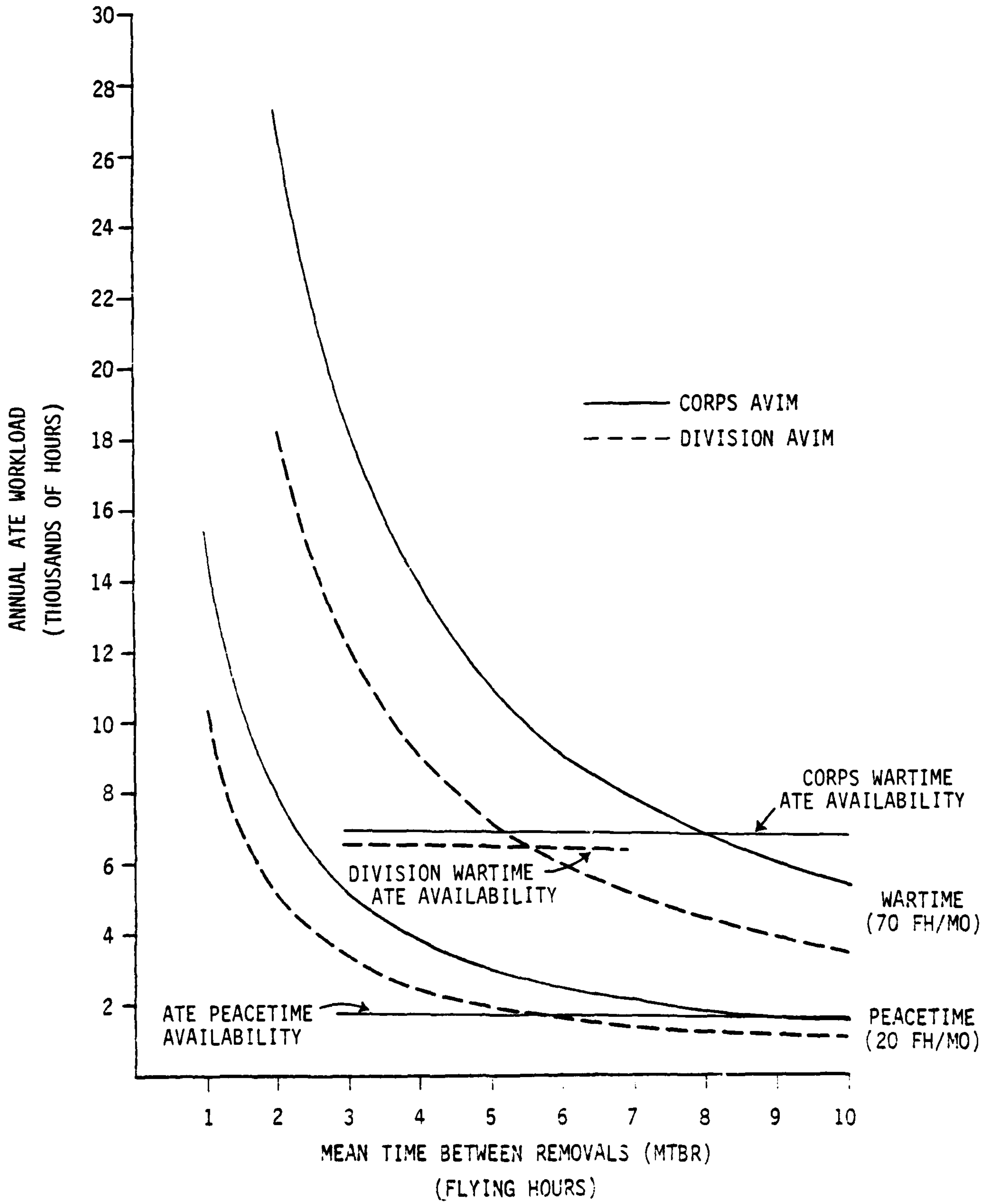
At corps AVIM, one MSM-105(V)2 would be adequate only if the wartime MTBR of the AH-64 is eight flying hours or better (in peacetime, 10 flying hours or better). Although an MTBR of eight hours is less than the MTBR projected by the AH-64 Program Manager, it is substantially higher than that experienced in the latest operational tests.

Throughout our analysis, we have used the term "wartime" to refer to a flying hour program of 70 hours per month per helicopter. Surge requirements during a high intensity conflict could require as much as 120 hours per month. One MSM-105(V)2 cannot handle the workload from surge operations at either corps or division AVIM.

ACCURACY OF THE ANALYSIS

This analysis is based on numerous assumptions about the ATE (reliability, maintainability, mobility, test accuracy, etc.) and the system it is

FIGURE 4-1. ATE WORKLOAD VS. ATE AVAILABILITY



to support, the AH-64 (deployment plans, flying programs, LRU removal rates, NEOF rates, etc.). We believe our assumptions are reasonable. However, without good data, any analysis of the type presented here must be considered only an educated guess.

The Army needs to do better than guess at its test equipment requirements. ATE is not a convenience to AH-64 support; it is a necessity. The maintenance plan for the AH-64 assumes that the ATE programmed for each maintenance echelon can accomplish the workloads generated for that echelon. If it cannot, LRU repair turnaround times will become long, inventories of spare LRUs will be exhausted, and aircraft combat operational availability will plummet.

APPENDIX A

THE AH-64 APACHE

The two engines of the AH-64 (T-700-GE-701 turbine engines of 1690 shaft horsepower each) drive via gearboxes a four-bladed main rotor and tail rotor. The aircraft has a tandem cockpit arrangement with the pilot located aft and the copilot-gunner in the forward crew station. Armament consists of the HELLFIRE missile, 2.75 inch rockets capable of delivering a variety of ordnance, and a 30-mm automatic gun.

The HELLFIRE is a terminally guided, anti-tank missile, currently equipped with a laser-guided seeker. The AH-64 can carry up to 16 missiles which are fired in single-, rapid-, or ripple-fire mode. A laser beam must be positioned accurately on the target during the terminal phase of the missile flight path. The laser designation can be accomplished either by the gunner using the TADS or remotely by a ground or other airborne laser designator. This terminal guidance concept permits either direct or indirect fire.

The gun is mounted in a flexible turret underneath the aircraft. It is a new, externally powered, single-barrel gun with a chain-operated bolt mechanism. Principal fire control is through the gunner's target acquisition designation sight with gun pointing automatically controlled by the fire control computer. As a backup, the pilot may fire the gun in a degraded accuracy mode using his integrated helmet and display sight system.

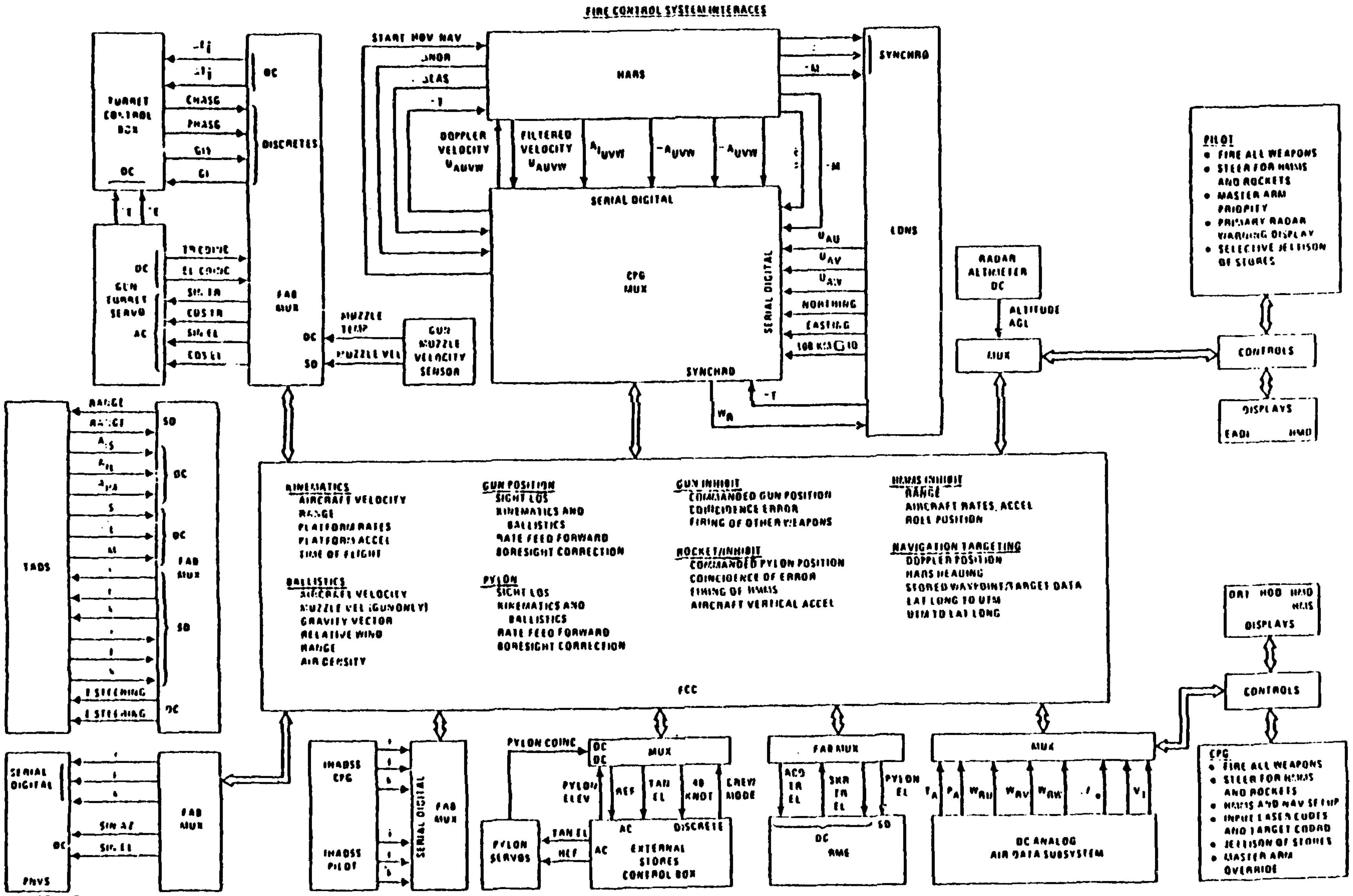
The rockets are carried in four 19-tube launchers providing a maximum payload of 76 rockets. The pylons are articulated, and, under control of the fire control computer, permit accurate firing without trimming the helicopter. Rockets are fired by the gunner using the target acquisition designation sight

or, as a backup mode, by the pilot using the integrated helmet and display sight system. Rockets may be fired singly or in salvos.

The key to this weapon system's capability of finding, aiming at, and killing targets day or night is the target acquisition designation sight and pilot night vision sensor system located in a turret in the nose of the aircraft. The target acquisition designation sight, installed in the lower turret assembly, is used for target search, detection, and designation. It is divided into two subassemblies, the day sensor and night sensor, both boresighted to a common line of sight. The day sensor includes direct-view optics, day television, laser spot tracker, and laser range-finder/designator. The night sensor includes a forward-looking infrared sensor which transforms thermal radiations into imagery projected on either a heads-down or heads-up display for the gunner who can select different fields of view. Once a target is acquired and designated, the system automatically tracks the target, permitting precise delivery of ordnance on both stationary and moving targets. The pilot night vision sensor, located in the upper turret assembly, provides the pilot with adverse weather flying capability day or night. It consists of a gimballed (azimuth and elevation) forward-looking infrared sensor which responds to the position of the pilot's head through infrared-optical coupling. The forward-looking infrared imagery and critical flight parameters are displayed to the pilot through the integrated helmet and display sight system, which consists of a cathode ray tube and a single monocle in front of the pilot's eye.

The capabilities outlined above are achieved through a sophisticated fire control system which integrates sensors, controls and displays into a closed-loop multiplex system including 16 microprocessors associated with 13 subsystems. This integrated system is illustrated in Figures A-1 and A-2.

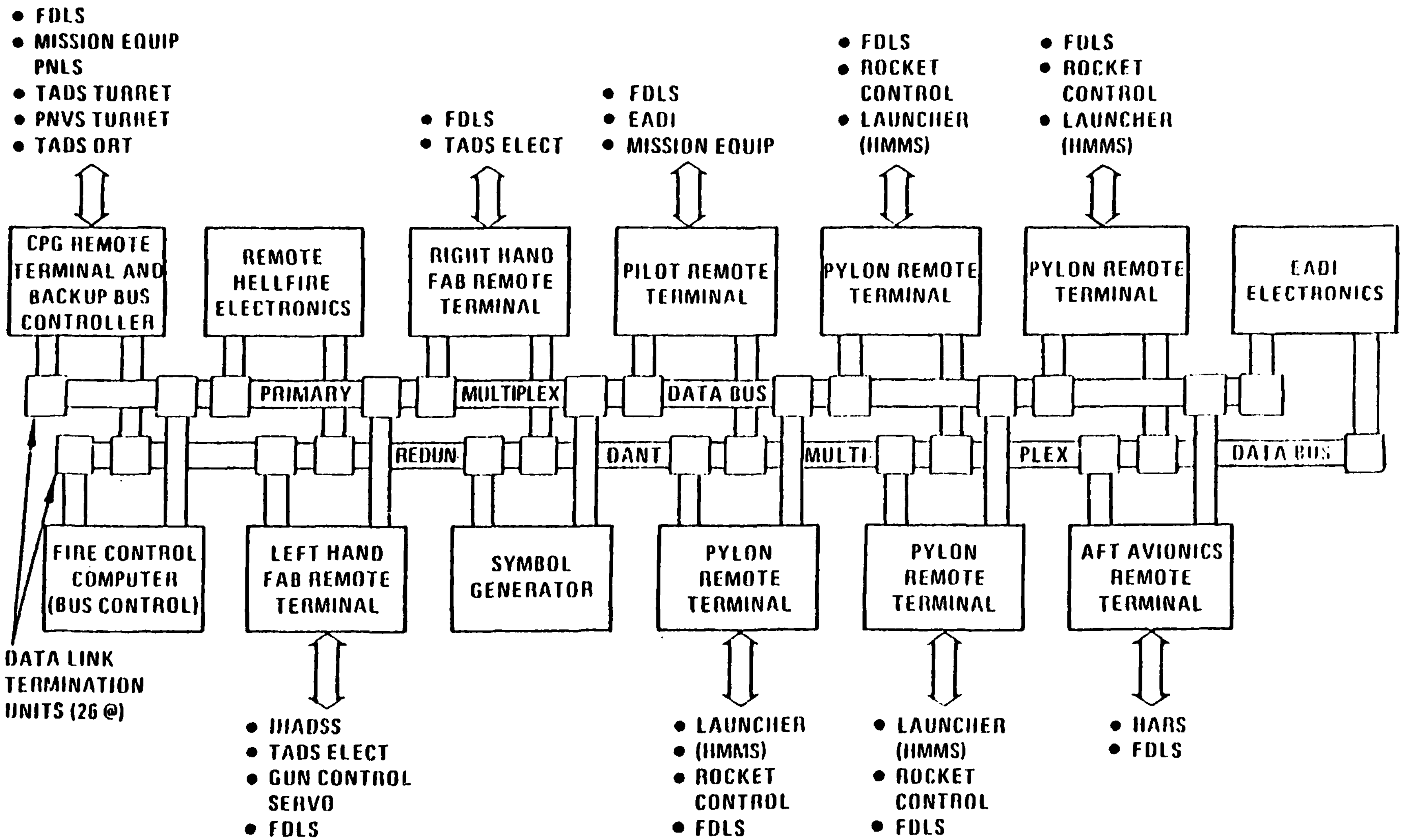
FIGURE A-1. FIRE CONTROL INFORMATION FLOW



800198-22

Source: Advanced Attack Helicopter, Computer Resource Management Plan, AAH Program Manager's Office, June 1980 (Revised 1 August 1980).

FIGURE A-2. YAH-64 MULTIPLEX SYSTEM BLOCK DIAGRAM



Source: Advanced Attack Helicopter, Computer Resource Management Plan, AAH Program Manager's Office, June 1980 (Revised 1 August 1980).

ORGANIZATIONAL CONCEPT

Under current tactical doctrine (known as Aviation Requirements for the Combat Structure of the Army (ARCSA) III, first approved in 1977), the Army employs and supports attack helicopters in the following force structure. Each division has one attack helicopter battalion, composed of:

- Headquarters and Headquarters Company,
- Division Aviation Company ("A" Co, controlling aerial observer and scout helicopters),
- Two Attack Helicopter Companies ("B" and "C" Co, each authorized 21 AH-1, 12 OH-58 and 3 UH-1 helicopters),
- Transportation Aircraft Maintenance Company ("D" Co, providing AVIM support to all divisional aircraft),
- Combat Support Aviation Company ("E" Co, providing lift for repositioning/resupplying troop units with 23 UH-1 or 15 UH-60 helicopters authorized).

Due to manpower and funding constraints, the "E" company is not fielded with all divisions. Doctrinally, each division's armored cavalry squadron also has one air cavalry troop but, due to force level constraints, only four active divisions are authorized this unit. (USAREUR elected to delete the air cavalry troops to create assets for additional attack helicopter companies).

Non-divisional units employing attack helicopters include the armored cavalry regiment deployed in the forward area and combat aviation group in the corps area. The two armored cavalry regiments fielded in USAREUR (one per corps) are organized differently from those in the Forces Command. Each has one attack helicopter company (21 AH-1, 12 OH-58, and 3 UH-1 helicopters) organized into three platoons and supported by its organic service platoon (AVUM). The combat aviation group concept was never fully implemented in USAREUR: corps aviation intermediate maintenance (AVIM) remained under the corps support command instead of under the combat aviation group headquarters as recommended by ARCSA III. Doctrinally, the combat aviation group has a

general support aviation battalion, comprising two medium lift helicopter companies (CH-47) and one combat support aviation company, and a combat aviation battalion comprising three attack helicopter companies. The latter companies have not been fielded yet in USAREUR due to a shortage of attack helicopters.

The major thrust of the ARCSA III reorganization was a standardization of the aviation force structure among different types of divisions, and a consolidation of divisional AVIM within the transportation aircraft maintenance company. The next major force structure change is that planned under Division 86/Army 86. The major thrust of that change is a consolidation of aviation unit maintenance (AVUM) at the battalion headquarters level, eliminating maintenance billets from the individual companies.

The new Army 86 organizations planned are the divisional air cavalry attack brigade and the corps aviation brigade. The air cavalry attack brigade consolidates all divisional combat and combat support aviation elements under a fourth maneuver brigade headquarters in the division. It consists of two attack helicopter battalions, each comprising three attack helicopter companies, and a headquarters and headquarters company which includes AVUM; one combat support aviation battalion which is similar to the present combat aviation battalion minus the attack helicopter companies, i.e., the combat support aviation battalion includes the transportation aircraft maintenance company providing AVIM for all divisional aviation; and one air cavalry squadron comprising two ground and two air cavalry troops. Each attack helicopter battalion has 21 AH-1 attack helicopters and the air cavalry squadron has 8, for a total of 50 AH-1 per air cavalry attack brigade. The corps aviation brigade has the same assets as the combat aviation group but is organized differently. It includes three attack helicopter battalions (21

AH-1 each) and AVUM. AVIM remains under the corps support command but is consolidated in an aviation support battalion comprising a variable number of transportation aircraft maintenance companies (3 to 6 depending on density of aircraft supported) for area AVIM support and backup support to divisional AVIMs. The armored cavalry regiments will also be restructured but without affecting the attack helicopter company.

APPENDIX B

ARMY AUTOMATIC TEST EQUIPMENT

AN/USM-410 PROGRAM HISTORY

The Army's ATE program dates back to 1967 when the Army Materiel Command completed a draft qualitative materiel requirement for computer-controlled automatic test equipment. The concept entailed a family of general purpose ATE for employment at DS, GS and depot levels in support of Army materiel in the 1975-1990 time frame. Feasibility and cost-effectiveness studies were performed by two contractors, RCA Corporation (RCA) and General Dynamics Electronics Division, under contracts with the Army Electronics Command. In view of the anticipated need for depot-level testing of radios, the development effort first concentrated on an ATE version for installation at depots and manufacturer's plants; this version was named Electronics Quality Assurance Test Equipment (EQUATE). In 1971, RCA won the competitive contract for procurement of a prototype EQUATE system, integrating commercial, off-the-shelf equipment into a general purpose ATE for fixed-plant installation. The system was type-designated AN/USM-410(V) as pre-production equipment. In 1975, the Army Security Agency selected the system as its standard ATE for testing and diagnostics of line replaceable units (LRUs) and printed circuit boards (PCBs) for all of its signal intelligence/electronic warfare systems. As a result, additional USM-410 systems were procured in support of TPS development.

In March 1975, a letter of agreement between the Training and Doctrine Command and Army Materiel Command was signed to initiate a program to investigate the operational, technical and logistical concepts of a family of

automatic test support systems (ATSS) and to support development of two ATSS configurations, one for avionics (capable of supporting the AAH) and one for electronics (capable of supporting TACELIS, TACFIRE, TRI-TAC systems, and high-density combat communications equipment). The requirements document (the Letter of Agreement) provided for development of one advanced development prototype at $4.6 million, excluding research and development funds from the PMs for AAH and TRI-TAC, and the Army Security Agency; completion of the required operational capability statement in 1979; and start of engineering development for two prototypes in 1979. The Letter of Agreement projected a procurement cost of $0.8 million (FY74 dollars) per USM-410 for a 100 unit buy. The program was initiated in 1975 with a six-month field test of the prototype USM-410 mounted in a semi-trailer to assess its potential at direct and general support maintenance levels in accordance with the original concept for computer-controlled ATE. The evaluation was favorable; the test report emphasized the potential benefits from increased diagnostics capability offered by ATE compared to manual test equipment.

An ATSS special study group convened in May 1976 to review implementation of the Letter of Agreement. It was agreed that the study group would be responsible for development of fully militarized USM-410 core systems and associated software which would be provided as government-furnished equipment to the PM, AAH and the Army Security Agency who would be responsible for development of the additional hardware and software required in support of their particular systems. For unidentified reasons, this agreement was later abrogated in the sense that the USM-410 core systems delivered by PM, ATSS to PM, AAH and the Army Security Agency in 1977 were commercial hardware and the research and development budget for militarization ($20 million for program years FY78 through FY80) was eliminated. The ATSS program proceeded with a

field test of the general support configuration (GS-ATSS), combining the van-mounted USM-410 test station with a van-mounted PCB repair station. This field test, conducted during the first half of 1978 in U.S. Army Europe (USAREUR), was the first phase of operational testing (OT I) of the GS-ATSS. The vans were moved to and operated at the 881st Maintenance Battalion (Hanau), 71st Maintenance Battalion (Nürnberg), with a general support contact team supporting the 1st Armored Division Organizational Communications-Electronics (C-E) Shop (Illisheim), and the Pirmasens C-E Maintenance Center (PCMC). (The latter is a special repair activity manned by German nationals performing much of the general support/depot-level electronics maintenance in USAREUR under a host nation support agreement with the Federal Republic of Germany.)

Based on OT I results, the PM, ATSS concluded that:

- Commercial ATE can operate effectively in a mobile configuration in the Army's field environment.
- Soldiers can operate the ATE and repair PCBs.
- PCB repairs at general support should increase operational readiness of supported weapon systems by reducing turnaround times and pipeline stockage requirements.

Some problems that surfaced during OT I included: test program set formats and acceptance criteria; low reliability of the ATE (45 hours MTBF); and power supply problems. (Maintenance support for the ATE was provided by contractor personnel on site).

In July 1978, the proposed required operational capability (ROC) for GS-ATSS was submitted by the Training and Doctrine Command to the Department of the Army. In August, a special program review approved a limited procurement type classification for 41 commercial USM-410 systems procured or to be procured prior to FY82 to meet the need for interim ATE until the planned availability of GS-ATSS in FY83. The ROC, however, was disapproved by the

Department of the Army on the grounds that it was a major acquisition program requiring a mission area analysis and mission element need statement. The Department of the Army expressed its support for using the commercial USM-410 to meet immediate operational needs. The proposed mission element need statement for a "Family of ATSS" (general support, direct support and organizational maintenance levels) and the ROC for GS-ATSS were (re)submitted in March 1979. The ROC identified the commercial USM-410 as a core system, to be augmented as needed by the PMs of supported weapon systems; it required van-mounted equipment to meet certain environmental conditions (category 1 through 8 of AR 70-38) during operational use, but permitted modification kits (including power requirements) to meet those conditions during transit and storage.

In December 1979, the U.S. Army Materiel Development and Readiness Command (DARCOM) made the decision to standardize Army ATE and adopt the USM-410 as the standard, general-purpose ATE for use at general support and depot levels. This decision terminated further development or procurement of other ATE. In June 1980, DARCOM promulgated its Implementation Plan for Single ATE (GS and Depot) Policy. This document included ground rules for determining whether system-peculiar ATE already in development would be accepted in lieu of the USM-410. The policy, in fact, emphasized the need for standardization and approved a one-shot cost increase, if necessary, to convert to USM-410 when longer-term cost or readiness benefits could be anticipated.

CONFIGURATION

There are two mobile versions of the USM-410 being developed for tactical units. The AN/MSM-105(V)1 is a van-mounted version for employment at general support maintenance units. The AN/MSM-105(V)2 is a shelter-mounted version

for employment at aviation intermediate maintenance units supporting the AH-64 attack helicopter.

AN/MSM-105(V)1

The electronic equipment test and repair station AN/MSM-105(V)1 consists of one each of the following:

- Electronic Test Facility (ETF), van-mounted
- Electronic Repair Facility (ERF), van-mounted
- Passageway assembly (stored in the repair van)
- Electric power plant, trailer-mounted.

The power plant consists of two generators, each mounted on a wheeled trailer; one of the two generators is backup. The generator provides 60 kilowatt, 60 Hertz alternating current. The ATE requires 115/208-volt, 3-phase, 60 Hertz power so that the generator (apart from mobility considerations) is necessary as a power source at locations where no commercial 60 Hertz power is available (e.g., Western Europe). The ATE fielding plan does not include power conversion equipment though power converters are scarce in USAREUR.

The ERF contains a counter-top work bench with four repair stations, an oven for conformal coating of electronic modules after repair, and a quality assurance station with microscope. Each repair station is equipped with soldering equipment and a set of tools. Two 18,000 BTU air conditioners provide environmental control (cooling and heating).

The ETF contains the electronic test station (AN/USM-410(V)2), a power protect unit (wall-mounted control panel to protect the ATE against power fluctuations), a digital card tester (AN/USM-465), and bench-mounted test, measurement and diagnostics equipment (TMDE) for troubleshooting the electronic test equipment itself. The latter includes: digital multimeter

(AN/ USM-451), digital RF voltmeter, RF signal generator, oscilloscope, AM/FM modulator and power meter. The digital card tester is a portable tester mounted in a transit case. The configuration of the electronic test station is described in Table B-1. Environmental control is provided by four 18,000 BTU air conditioners (cooling and heating) and one humidifier. Support equipment includes tools and general purpose, rack-mounted TMDE.

TABLE B-1. ELECTRONIC TEST STATION AN/USM-410(V)2

STATION[1]	ASSEMBLIES
Operator Control	Computer (ECLIPSE S/130) Operator's panel Disc drive unit
Power Supply	Regulated power supply (7 units) DC control unit DC calibration standard AC calibration standard AC control unit
Unit Under Test	Dedicated interface unit Low frequency stimulus drawer Power supply drawer Measurements/voltage sampler drawer RF synthesizer System clock
Programmable Interface	Programmable/regulated power supplies Universal test pointer drawer
Microwave Test	Microwave measurements drawer RF/microwave stimulus drawer Front panel connectors
Magnetic Tape	Tape transport Storage drawer
Video Display Terminal	Keyboard Video display Controller
Line Printer	(Single unit)

[1]Except for the video display terminal (VDT) and line printer, each station is mounted in a metal cabinet with blowers at the bottom.

AN/MSM-105(V)2

The AH-64 peculiar test and repair station AN/MSM-105(V)2 will be fielded in two configurations, one without ERF to be fielded at divisional AVIM, and one with ERF at corps AVIM. (The decision not to authorize PCB repair at divisional AVIM was made by the Deputy Chief of Staff, Logistics in September 1981.) The ERF is physically identical to the ERF associated with the AN/MSM-105(V)1. The ETF, however, contains about three times as much test equipment. Instead of a single van, it is housed in two ISO[1] shelters. The two power generators (mounted on four-wheel trailers) and air conditioners (three per ISO shelter) for the MSM-105(V)2 differ from those used with the MSM-105(V)1.

The MSM-105(V)2 ETF includes the same test equipment as the MSM-105(V)1 facility (the USM-410 configuration installed is the USM-410(V)4 which equals the USM-410(V)2 less one microwave rack) augmented by the following equipment:

- AC station
- Power station (converting 60 to 400 Hertz for avionics)
- Interface station (for standard 1553 databus)
- Photometer (to test AH-64 displays)
- Pneumatics station
- Motion subsystem
- Electro-optical bench
- Electronics station.

TEST AND EVALUATION

Final Department of the Army approval depends on successful completion of developmental and operational testing. The third phase of developmental

[1]International Organization for Standardization.

testing, DT III, was completed in September 1981. The test was reported to be a disaster: "The AN/MSM-105 is unsafe to operate and maintain in a deployed state." The test also revealed serious deficiencies in reliability and maintainability of the ATE, but the system was subjected by the Test and Evaluation Command to harsher treatment than is usually expected in the planned operational environment. A follow-on assessment of reliability, availability and maintainability is scheduled for May and June 1982. OT III is scheduled for completion by the end of the calendar year 1982. Based on the poor DT III results, planned fielding has been deferred. The Commanding General, CECOM has indicated that the MSM-105 will not be fielded unless and until it can be operated and supported in the field environment. The approved acquisition objective for the MSM-105(V)1 is 36 (35 fielded at general support units, one as training equipment at Fort Gordon); none will be fielded with the reserve components. The planned deployments of MSM-105 are shown in Table B-2.

TABLE B-2. AN/MSM-105 PROCUREMENT DEPLOYMENT PLAN

ITEM	LOCATION	FY82	FY83	FY84	FY85	FY86	TOTAL
MSM-105(V)1	CONUS	1[1]	3	5	3	4	16
	USAREUR	1[2]	3	6	2		12
	KOREA			1		1	2
	WESTCOM[3]					1	1
	AMSF[4]				4		4
MSM-105(V)2	CONUS[5]	1[6]					9
	USAREUR[5]						7

[1] Installed at Fort Gordon as training equipment.

[2] Installed at PCMC.

[3] Western Command.

[4] AMSF = Air Maintenance Support Facility of Intelligence and Security Command.

[5] Employment depends on AH-64 employment decision; program schedule not available at present; total figures reflect 1981 program review.

[6] Prototype used for AH-64 OT II.

COMMERCIAL VS. MILITARIZED TEST EQUIPMENT

Normally, militarized equipment (design, manufactured and tested in accordance with military specifications for use in the planned operational environment) provides a higher degree of reliability, maintainability and durability under extremes of environmental conditions encountered in the field, but it is more expensive than commercial equipment (see Table B-3).

TABLE B-3. COMPARISON OF ENVIRONMENTAL SPECIFICATIONS

CONDITION	AN/USM-410	MIL-T-28800B[1] (CLASS 4)	AR 70-38 (CAT 7)
Temperature			
Non-Operating	0°C to 66°C	-62°C to +85°C	-37°C to +52°C
Operating	16°C to 32°C	0°C to 55°C	-37°C to +71°C
Relative Humidity	95% (non-condensing)	100%	100%
Vibration	Common Carrier[2]	3G	--
Shock	Common Carrier[2]	30G	--
Bench Handling	--	4-inch Edge Drop	--
Salt Atmosphere	--	5% Salt Solution	--

[1]All conditions applicable inside enclosure without air conditioning/heater.
[2]Common Carrier: Van equipped with air-ride suspension--maximum speed of 3 to 5 mph over unimproved roads.

The PM, TMDS informed us that the cost-effectiveness of militarization had been evaluated. The contractor was requested to conduct a preliminary analysis and submit a proposal for militarizing the USM-410 hardware. RCA's proposal indicated a requirement for an additional $20-$30 million research and development funds and a doubling of the recurring (procurement) costs, compared with fielding the commercial equipment. Given this information and the available or anticipated budget for the ATE program, the PM, TMDS decided that militarization would not be cost-effective. The line printer is the only major item in the ETF that is militarized; it is the same as the printer used

in the TTC-39. In this context, it is noteworthy that the Department of the Army originally deemed militarization necessary and provided $20 million for that purpose in the Army Security Agency's budget request for program years 1978-1980. With the ATE development mission centralized under the Program Manager for Automatic Test Support Systems (PM, ATSS) (now TMDS) within the Communications Research and Development Command (now CECOM) in 1975, this assessment apparently changed.

Past studies have recommended that the Services adopt commercial test equipment in view of reduced cost, rapid technology changes, duplication of development effort, and standardization. But the same studies have also pointed out the need to make specific provisions for supportability when using commercial equipment, including development of a complete integrated logistics support plan and emphasis on self-test performance (see: Industry/Joint Services Automatic Test Project, Final Report, June 1980).

MOBILITY

Mobility characteristics of the ATE are important in wartime, because tactical conditions may require frequent repositioning of the test facility. Army doctrine specifies that the mobility requirement for divisional shops is one move every 72 hours with a mobility factor of 50 percent (percentage of equipment and parts that can be moved in one haul with organic transportation capability authorized in the table of organization and equipment); for corps level general support units, the mobility requirement is once a week with a mobility factor of 10 percent. Army studies, however, have suggested that this requirement may underestimate the mobility required in a high-intensity combat scenario. For example, one of the concepts espoused by the 1979 Department of the Army Study (entitled "Phase II: Logistics Operations in the

COMMZ") states:

> "The Corps GS base may be required to move often and on short notice which generates a significant risk of permanent loss of supplies and equipment."

This concept is now included as logistics guidance in Training and Doctrine Command Pamphlet 525-12, Operational Concepts for Communications Zone (COMMZ) Logistics Operations (July 1981).

Inter-theater movement of the MSM-105(V)1 by air represents one full load for the C-5A, or more than one load for other transport aircraft. The latter would also require modifications to the vans. The system is not transportable by rotary-wing aircraft nor by most aircraft of the civil reserve airlift fleet. Marine transportation is possible in all types of vessels used for shipping Army equipment except in the LARC-V.

In-theater movement by rail is not possible due to the shocks inflicted on the equipment when coupling/decoupling freight cars. With regard to highway transportation, the requirements document specified that the system be capable of being transported at the following maximum speeds without adverse effects to its operational capability:

- 55 MPH over main roads
- 30 MPH over secondary roads
- 5 MPH over unimproved roads or off-road (across distances sufficient for leaving improved roads to reach tactical positions).

Testing has indicated that the system is able to meet this requirement in spite of the use of commercial test equipment. For earlier tests, the system was made more rugged using heavy metal cabinets/racks, shock mounts and vibration restraints in standard Army vans (M574E1, for Test Station, M373A2 for Repair Station). During OT I only a few cases of loose connectors were attributed to movement. For the production prototype configuration used in DT/OT III, the two vans are 35-foot, 8-wheel, 10-ton-capacity semi-trailers

(XM-991 for the ETF and XM-995 for the ERF) equipped with air suspension; the air suspension system has apparently solved the problems of movement-induced failures and misalignments. The ISO shelters used for the AN/MSM-105(V)2 are similarly mounted on flatbed trailers with air suspension.

Another effect of movement is the time lost in preparing for and setting up after a move. Testing suggests that approximately one hour is required each for teardown and setup. The latter, however, does not necessarily mean that the system is "up" within one hour; this depends upon the duration of the movement, as it may affect environmental control of the test station.

ENVIRONMENTAL CONTROL

The fact that ATE and associated calibration standards are very sensitive to temperature and humidity is well known. Ability to provide strict environmental control is important to the operational suitability of ATE. Even when the equipment is not used (e.g., at night in single shift operation), it may be necessary to continue environmental control in order to avoid excessive delays in getting the ATE operational. The extent of such delays would depend on ambient temperature, physical mass of the equipment, and duration of exposure to temperatures beyond design range.

The following information is available on the MSM-105(V)1 ETF . If the temperature in the van is below 35°F, standard operating procedure is to turn on the blowers to bring the temperature up to 35°F. When the temperature is 35°F or higher, the operator turns on the warm-up of the calibration standards. Only when the temperature in the van is 68°F is the operator allowed to turn on the system. Charts are available to show the time lapse; for example, for a starting temperature of 35°F, the four air conditioners bring the temperature to 68°F in two hours; from 0°F in four hours; from -30°F in 15 hours; and from +150°F in ten hours. Once the system has been turned

on, the ATE operator runs the so-called warm-up tape which is the operating software monitoring the functions within the system and reporting when the system has stabilized. This stabilization takes a minimum of 30 minutes but may take up to two hours if the calibration standards are not properly warmed up. The implication is that substantial delays are possible if the air conditioners are not left on; thus, constant power is required from the generator. During movement of the van, no environmental control is provided so that, depending on ambient temperatures, the actual down time of the system may be much longer than the physical movement time plus tear-down and set-up times.

Testing confirmed the ability of the system to keep the temperature in the van within design limits for operational use under ambient conditions of -50°F to +160°F (120°F plus sunloading effect). It also demonstrated, however, that low or high temperatures in the van caused sufficient temperature stress to necessitate routine maintenance. Testing showed that without operating the humidifier/dehumidifier the commercial equipment tended to rust, but that routine maintenance could restore the system to operational status.

In summary, the availability of environmental controls and required power supply is crucial. Both generators and air conditioning equipment have notorious weak support in USAREUR, especially non-divisional equipment. The redundancy provided in the MSM-105(V)1 (two generators vice one required, four air conditioners vice three sufficient) tends to compensate somewhat for this weak support. However, the ATE tests to date have noted serious problems with the reliability of the generators and/or environmental control units.

TEST PROGRAM SETS

Storage and Handling

A TPS comprises the fault-diagnostic software loaded on tape or disk, the required interconnection device (ICD) and associated cabling, and

the test program description referred to as English Language Test Design Document. For PCB repair, the MSM-105 is designed so that the same ICD can be used for a wide variety of different boards. For LRU repair, most LRUs require a peculiar ICD. The MSM-105(V)1 vans have no storage space for ICDs, so that they must be stored in a van or storage truck collocated with the test facility. The PM, TMDS Materiel Fielding Plan for AN/MSM-105(V)1 points out the need for a dedicated and secured physical storage facility providing cabinets for storage of magnetic tapes (test programs), disk packs containing ATE operating software, and bins for storing ICDs and associated cabling. Such a facility, however, is not included in the materiel fielding plan. Physical storage requirements for ICDs are estimated by the Program Manager's office as follows: For LRU checkout, one to three LRUs typically share the same ICD with a weight of 5-25 lb and size of one cubic foot. For PCB repair, up to 30 types of PCBs share the same ICD with a weight of 5-15 lb and size 1.5 cubic feet. For example, based on the systems supported, the typical general support unit in USAREUR (e.g., 881st Maintenance Company at Hanau) would need only 3.6 cubic feet for ICD storage in 1982 (PCBs from TACFIRE and FIREFINDER). In 1983 this would grow to 155 cubic feet based on additional systems supported (MLRS, TEAMPACK, TACJAM, AN/UGC-74).

The configuration of the MSM-105(V)2 (with the ETF housed in two ISO shelters each measuring 8 x 8 x 20 feet expanded) provides much more space than the MSM-105(V)1 vans. As a result, TPSs, ICDs and cables for AH-64 LRUs/SRUs will be stored on site with the test station in the same ISO shelter.

The Materiel Fielding Plan also points out the need for periodic preventive maintenance of the ICDs (physical inspection and/or running ICD self-test programs to ascertain proper functioning) and for environmental

conditioning of magnetic tapes/discs at least 24 hours before use at the temperature and humidity equivalent to those within the ATE test facility. These requirements would obviously influence the job scheduling for the ATE.

Test Program Quality

Test program quality combined with ATE operator skills have a direct impact on maintenance efficiency and LRU/SRU turnaround time. By program quality, we refer to such measures as fraction of faults detected, fraction of faults isolated, fault-isolation resolution (size of ambiguity group to which faults are localized), fraction of false alarms (i.e., TPS detects a fault even though the LRU/SRU is within design tolerances), and fraction of erroneous fault isolations. Precise, quantitative data for these measures are not available. Empirical data based on ATE experience in the Services, however, permit us to make some qualitative observations.

TPS design requirements, if CECOM is the procuring agency, are stated in terms of a goal of 100 percent fault detection and 95 percent fault isolation. TPSs are typically developed under a "cost plus" contract whereby tradeoffs between additional cost and additional fault-isolation capability are determined in preliminary and critical design reviews. CECOM's experience is that the "typical" TPS for PCB diagnostics provides close to 100 percent fault detection with a fault-isolation resolution to an ambiguity group of L or fewer components, FIR(L), as follows:

$$FIR(1) = 75\%; \; FIR(3) = 90\%; \; FIR(5) = 95\%$$

Thus, about 25 percent of the failures require manual probing by the ATE operator to isolate a failure to a single component. Manual probing is normally limited to one or two test points and fully guided by the test program. Due to a recent reorganization, the TPS Group under CECOM's Maintenance Engineering Directorate was unable to give us TPS acceptance and

verification test data, field-performance data, or engineering changes required. The actual costs of TPS development incurred by the Army to date for PCBs show most with a wide range from $30,000 to $100,000, and some up to $200,000. The main cost driver is not PCB complexity, but the testability specifications of the hardware. For example, some of the systems currently being fielded by the Army did not include in their original design specifications a requirement that modules be testable on the USM-410 family of ATE.

The above estimate of TPS quality for PCBs agrees with the information we received from PCMC where a USM-410 has been operative since 1978. The ATE operators (electronics technicians of German nationality) told us at the time (December 1979) that 25 to 30 percent of the PCBs processed by PCMC require manual probing, mostly guided by the test program. Only a small percentage required the use of schematics and unguided probing for fault isolation. (The boards involved were primarily from TACFIRE and TSQ-73.)

The Naval Air Engineering Center reports that its experience with TPSs for PCBs, based on application of standard automatic test program generation software for digital boards of average complexity (density), typically results in 80 to 85 percent fault isolation. This level could be further improved by spending additional time and money prior to TPS fielding, which might or might not be cost-effective. The alternative is to field the TPS and develop improvements based on user experience. In contrast, automatic test program generation is not yet technically possible for analog boards. TPS development for these boards typically requires one man-year of effort and, at the first pass, may provide 60 percent fault isolation for the typical board, if the programmer is an expert. Getting the TPS up to an acceptable level requires careful management, closed-loop feedback from the field to develop effective engineering change proposals, and lots of growing pains.

For LRUs from the AH-64, we were told that the statement of work for TPS development included the requirement of 98 percent fault detection and isolation with a false-alarm rate of two percent or less (in accordance with the AAH Materiel Need), supplemented with the requirement that fault isolation be to a single removable module within the LRU without need for LRU disassembly and manual probing. Because of limited testability characteristics of some LRUs, this requirement had to be waived in cases where access to internal test points was necessary to achieve the desired level of fault isolation. The need for such deviations was reviewed in critical design reviews and documented in the English Language Test Design documentation of the TPS involved. Demonstration tests have been conducted on 41 TPSs delivered to date.

The Automated Systems Division of Tobyhanna Army Depot uses a simple formula for the number of tests (failure insertions) required for a demonstration as a function of the number of test paths within the TPS. The actual failures selected are taken randomly from the contractor-developed fault list (typically, 40 to 50 faults based on failure mode effects and criticality analysis) plus some failures not on this list but selected based on experience. The success of the TPS in fault-isolating the latter type of failures is a prime factor in acceptance of the TPS. In contrast, CECOM reportedly limits its acceptance and verification testing to a random selection from the contractor-developed fault list. The results for three sample cases are shown in Table B-4.

Overall, TPS quality for AH-64 LRUs may be estimated at close to 98 percent fault isolation to a group of five modules or less and, on the average, 75 percent isolated to a single removable module under laboratory conditions. To maintain this performance in the operational environment,

where different failure frequencies and new failure modes of LRUs will be encountered, will of course require a careful TPS configuration management program with input from the users (ATE operators) for documenting test program deficiencies which must be corrected through engineering change proposals.

TABLE B-4. SAMPLE DEMONSTRATION OF AH-64 LRU TEST PROGRAMS

LRU IDENTIFICATION	NUMBER OF FAULTS INSERTED	FAULT ISOLATION RESOLUTION
202	4	1 fault isolated to 1 module 3 faults isolated to ambiguity groups of 2, 3 & 4 modules
214	11	3 faults isolated to 1 module 8 faults with average ambiguity of 2 modules
112	6	6 faults isolated to 1 module

TEST PROGRAMS FOR ATE MODULES

A separate category of TPSs consists of those designed to fault-isolate removable modules of the MSM-105 itself after they have been diagnosed as faulty by the system self-test software and removed/replaced from stock. The MSM-105(V)1 comprises about 350 electronic modules (88 types of modules, primarily PCBs) and 30 "black boxes" (commercial vendor items). The computer is one of these black boxes, but PM, TMDS plans to augment the diagnostic software to fault-isolate to the card level within the computer. A total of 62 TPSs is currently planned to fault-isolate MSM-105 modules; of these, 27 are go/no-go tests with the faulty boards repaired at depot (due to complexity) or throw-away, and 35 are diagnostic tests to fault-isolate boards to the faulty component for subsequent repair in the ERF. Additionally, one

TPS is planned for a standard ICD which is fielded with the MSM-105(V)1. So far, 25 of these TPSs have been delivered by RCA with 37 still in development. Experience at Tobyhanna Army Depot with these TPSs is reported as satisfactory.

TPSs for the additional test equipment in the MSM-105(V)2 have not yet been planned because the maintenance support concept for this augmentation equipment is still under review.

APPENDIX C

OPERATION AND SUPPORT OF AN/MSM-105

MAINTENANCE SUPPORT CONCEPT

AN/MSM-105(V)1

The maintenance concept calls for the ATE crew to perform all on-site services needed to operate, maintain and restore the system. Key to the success of this concept is the system's self-test diagnostic software. The requirements document for GS-ATSS specifies that the system will be able automatically to fault-isolate 90 percent of the failures to an ambiguity group of five or less removable units. The operator is to fault-isolate down to a single removable unit using manual TMDE or by replacing, one for one, the suspect units, and testing whether or not replacement has corrected the system failure. The support concept does not include backup support. Thus, the crew also has to resolve failure symptoms which are not automatically fault-isolated by the system. This task is assigned to the ATE supervisor/maintainer who must rely on technical manuals, experience and training.

The system contains about 275 types of removable units including vendor end items, cable assemblies and electronic modules (primarily PCBs). Based on a level-of-repair analysis, the support concept includes on-site screening of 27 types of PCBs (with the faulty ones evacuated to depot) and repair of 35 other types of PCBs, using TPSs developed for this purpose. The other LRUs are either repaired at depot or returned via depot to vendors for repair.

Field support is planned for the first year after fielding. This support consists of on-call assistance by a field maintenance technician who

will be backed up by a contractor technician. They are, however, not supposed to perform hands-on work, just to assist.

Calibration and repair support for internal calibration standards, general purpose TMDE and power supplies will be provided by the U.S. Army Meteorology Calibration Center. In USAREUR, this is the U.S. Army Test Equipment Support Activity, Europe, headquartered in Zweibrücken, with an area calibration and repair center in each Support Command (V Corps, VII Corps, and 21st Support Command). Each area calibration and repair center employs a number of area TMDE support teams, some in a fixed location for area support, some mobile for on-site support.

The normal ATE operating procedure would be to warm up and power up at the start of a shift. The full self-test program would normally not be run, just a shorter version (runtime 20 minutes). The system software automatically identifies which routine calibrations are necessary (based on set calibration intervals), computes adjustment factors and applies these adjustments in the software to compensate for calibration deviations. When a TPS is mounted and executed, the first segment is a survey preamble that checks the status of the test equipment to be used in the fault detection and isolation segments of the TPS. An ATE failure may thus be detected when running the system survey or while running a TPS. When a failure is detected, the operator must load the full self-test program, which will first verify the failure and then fault-isolate to an ambiquity group of LRUs, which are identified on the video display terminal and listed by the printer. Following the necessary remove/replace actions, the operator will verify system performance before proceeding with the TPS run.

AN/MSM-105(V)2

The additional test equipment housed in the MSM-105(V)2 consists primarily of Hughes augmentation equipment (various vendor equipments with

Hughes responsible for integration as prime contractor) and Martin Marietta augmentation equipment (electro-optical bench and other electronics test equipment). Maintenance support plans for this augmentation equipment have not been finalized. The intent is to procure self-test diagnostic software for each of the two augmentation segments which contain several hundred removable modules. Design reviews of which modules will be self-repaired using TPSs and which will be returned for depot-level or vendor repair are still in progress. The overall maintenance concept is similar to that for the MSM-105(V)1, although some backup maintenance support from AVIM shop personnel collocated with the MSM-105(V)2 is implied.

PERFORMANCE OF SELF-TEST DIAGNOSTIC SOFTWARE

AN/MSM-105(V)1

The self-test diagnostics are new computer software for the USM-410 family. The software was accepted by PM, TMDS in eight separate segments, using about 50 fault insertions in the acceptance test for each segment. The acceptance test results indicated that the software would be able to meet the 90 percent fault-isolation requirement. Field performance would, of course, depend on the quality of the failure mode effects and criticality analysis conducted by the contractor and the actual failure frequencies in the operational environment compared to engineering estimates.

DT III was conducted in two phases: the June-September 1980 test of environmental and transportability issues, and the April-September 1981 test of reliability, maintainability, system performance, electromagnetic interference, and TPS transportability. While DT III was not designed to provide a rigorous assessment of self-test performance, it was the first field test of this new software. Test results revealed serious shortcomings in maintainability caused by inability of the system self-test to diagnose faults accurately and consistently, and by inadequate technical manuals. (This was

the assessment of the U.S. Army Logistics Center observers at DT III; we have not reviewed the formal DT III Test Report by the Test and Evaluation Command which was scheduled for release in March 1982 but was unavailable to us in time for this report.) As a result, most of the required corrective maintenance during this test was performed by contractor personnel.

PM, TMDS is planning to improve the technical manuals to develop "new look" manuals for some of the ATE operator functions (FY84), and to improve the self-test diagnostics.

AN/MSM-105(V)2

No information is available on the self-test performance for the augmentation test equipment in the MSM-105(V)2.

SUPPLY SUPPORT

For the MSM-105(V)1, supply support consists of about 600 line items, including 334 lines for shop stock (components and piece parts for repairing the 35 PCBs from the USM-410 which are self-repaired) and 275 lines for the essential repair parts stockage list (ERPSL). The latter comprises the removable units from the USM-410 which are not self-repaired, including vendor items, cable assemblies and modules. (The term ERPSL denotes that stockage will be authorized regardless of demand history; normal stockage criteria are based on certain minimum levels of demands.) To reduce stockage costs, PM, TMDS has examined the extent to which the ERPSL could be consolidated. It is presently programmed for distribution as follows: 131 lines on site (approximate cost $110,000 per site, weight 50 lb., volume 4 cubic feet), 77 lines at each supply support activity (about $20,000 per supply support activity, weight 180 lb., volume 8 cubic feet), and 67 lines consolidated at corps GS level (about $220,000, weight 817 lb., volume 50 cubic feet). For USAREUR, with five systems employed in each corps (excluding one in Pirmasens and one

at Mainz Army Depot), the total cost of the planned ERPSL in support of the MSM-105(V)1 would thus amount to approximately $1.7 million. (V corps has two supply support activities, VII Corps has three). The revised AH-64 fielding plan would, of course, reduce the cost of the planned ERPSL. The components and piece parts required for repairs of LRUs and PCBs from the supported weapon systems are in the respective authorized stockage lists.

For the MSM-105(V)2, supply support plans are not yet complete.

PERSONNEL AND TRAINING

The training concept has changed several times due to the changes in ATE maintenance concept but also due to differences in training philosophy.

Original Concept

The original concept, as proposed by the PM, ATSS (now TMDS) office and in effect through 1978, was to have the ATE operator be a weapon system repairer with an additional three to four week course module in ATE operation. The ATE operator would thus have a weapon system repair MOS[1] (depending on the particular commodity supported), with an addition skill identifier to denote training in ATE operation. This concept emphasized the need for component knowledge and downplayed the need for ATE-oriented skills. At that time, of course, the ATE self-test was supposed to be virtually perfect (98 percent fault detection, 95 percent fault isolation with minimum ambiguity) so that the operator's job with regard to ATE maintenance was limited to following the remove/replace instructions generated by the self-test software at the module/instrument/card level. A skilled ATE maintenance technician would be responsible for both hardware and software maintenance beyond the capability of the operator and would have a new, ATE-specific (USM-410 family) MOS. These technicians would be located at a centralized revised general support center

[1]Military occupational specialty.

to provide on-site intermediate maintenance support to other centers operating the ATE and to repair faulty modules removed from the supported ATEs. At that time, of course, the planned ATE reliability was high (mean time between failures (MTBF) desired--500 hours; minimum acceptable value--250 hours) so that an on-site maintenance technician at each fielded ATE site would be unnecessary and impractical considering skill retention. The third type of skill required for ATE fielding was the card repairer in the ERF. This skill was never seen as a problem and was expected to require no more than the seven-week precision soldering course already in the training repertoire of the Signal Center and School.

Operational and Organizational Concept

The original job design and training concept was revised entirely in the Operational and Organizational Concept for AN/USM-410 (Revised), published by the U.S. Army Signal Center and Fort Gordon, June 1979. The revised concept was to operate/maintain all fielded versions of the USM-410 with personnel of identical MOSs regardless of commodity supported. No rationale was given for the decision to de-emphasize the requirement for knowledge of the unit under test (UUT) for the ATE operator. The MOS recommended for the ATE operator was the same new MOS 74X proposed at that time for tactical data equipment operator in view of the commonality of operator tasks. For UUT specific problems, the concept was that the ATE operator could rely on maintenance personnel in the GS unit to which the ATE was attached. For ATE maintenance, the revised concept recognized the need for a maintainer on site considering the limited number of ATEs to be fielded and their dispersed geographical locations. (Also, by this time, the expected level of fault isolation by the ATE self-test had been reduced to 90 percent.) The MOS recommended for the ATE maintainer was the same as the new MOS 34X proposed at

that time for tactical automatic data processing equipment technician. Because of the anticipated limited workload, the concept recommended combining the job of supervisor and maintainer in the same billet. This document noted that experience suggested that the card repairer's job was boring due to the repetitious nature of the work involved. It suggested that these billets initially be filled with regular maintenance personnel (certified as card repairer) on a rotational basis to/from other repair billets in the general support unit to which the ATE was attached. It also suggested that a study be conducted of the feasibility of a new MOS for card repair.

The operational and organizational concept proposed a "stand-alone", cellular team for each fielded version of the USM-410, providing for two-shift operation and flexibility for attaching the ATE to various supported units. The proposed organization is shown in Table C-1.

TABLE C-1. MSM-105 MANNING (OPERATIONAL & ORGANIZATIONAL CONCEPT, 1979)

POSITION	GRADE	MOS	NUMBER PER SHIFT Shift 1	Shift 2
Supervisor/Maintainer	E-6	34X30	1	0
Shift Leader/Maintainer	E-5	34X30	0	1
Chief Operator	E-5	74X30	1	1
Test Station Operator	E-4	74X20	1	1
Technical Inspector	E-5	Note	1	1
PCB/Module Repairer	E-4	Note	4	4
		TOTAL	16	

Note: Any weapon system repairer certified as card repairer.

Current Concept

Since 1979, various alternative training concepts have been considered which converged to the creation of a new, ATE-dedicated MOS with a career path from card repairer to test station operator and maintainer. The

MOS decision was approved in March 1982; the approved table of organization is shown in Table C-2.

TABLE C-2. APPROVED TOE[1] 29-360H (FEBRUARY 1981)

POSITION	GRADE	MOS[2]	NUMBER PER SHIFT Shift 1	Shift 2
Supervisor/Maintainer	E-6	35C30	1	0
Test Station Operator	E-5	35C20	2	2
PCB/Module Repairer	E-4	35C10	4	4
		TOTAL	13	

[1]Table of organization and equipment.

[2]35C20 and 30 for MSM-105(V)2 will have an additional skill identifier for electro-optical skills.

The formal program of instruction is in development and will be approved by mid-1983. In the interim, training courses adapted from a commercial training package developed by RCA are given to MOS 35B (Electrical Instrument Repairer) personnel. The course lengths are shown in Table C-3. The proposal is to require an electronic aptitude composite (EL) score of 110 and high school diploma (or equivalent) as prerequisites for course eligibility. The training concept is one of multi-level training to provide a career opportunity as well as minimum front-end training. Thus, the 35C10 course only teaches the student precision soldering. After reenlistment, the student can take the 35C20 course which teaches ATE operation, including organizational and direct support level maintenance tasks on the ATE itself, using only the self-test features of the system. After the second reenlistment, a person at the 35C20 level becomes eligible for the skill level 30 course, which includes electronics theory to teach him how to supplement the system self-test or overcome self-test shortcomings.

TABLE C-3. TRAINING PLAN

MOS/ SKILL LEVEL	INTERIM COURSE		FINAL PROGRAM OF INSTRUCTION (PLANNED)	
	Prerequisite	Course Length	Prerequisite	Course Length
35C10	35B10	7 weeks	EL≥110; high school	10 weeks
35C20	35B20	8 weeks	35C10	9 weeks
35C30	35B30	12 weeks	35C20	18 weeks

With the planned fielding of 34 systems (MSM-105(V)1 only) by FY86, manned at single shift, the total billet requirement is 238. The Military Personnel Center training plan identifies a training requirement of 293 personnel, permitting 45 attritions in training (an attrition rate of about 15 percent). (This excludes the personnel required for MSM-105(V)2 stations.)

Attrition in the interim courses for 35C20 and 30 has been low. This is, of couse, not predictive of future attrition in the final program of instruction. Students in the interim course are 35B20 and 30 personnel with several years of job experience as well as intensive technical training. The 35B course is no longer available to active army personnel with the 1980 merger of the 35B and 35H (Calibration Specialist) MOS into a single MOS(35H) combining test equipment repair and calibration. The 35B course is still given to reserve component personnel but the duration and difficulty of the course have decreased since the introduction of the all-volunteer force (see Table C-4). In summary, while the present indications may be that the training of ATE operators and supervisors is successful, the future training program for these personnel relies to a large extent on on-the-job training of course graduates. The radical decrease in the technical qualifications of students in the 35C20 course must affect skill acquisition in the course when the course duration is held virtually constant (increased from eight to nine weeks).

TABLE C-4. MOS 35B TRAINING INFORMATION

PREREQUISITE	1971	CURRENT
	EL = 110	EL = 90
Training Philosophy	Skill Level 20 Course followed by Skill Level 30 Course for most promising graduates	Skill Level 10 Course Only
Course Duration	35B20: 28 Weeks 35B30: 19 Weeks Total: 47 Weeks	35B10: 23 Weeks

MSM-105(V)2

The PM, AH-64 office has taken the position that, in view of the limited UUT knowledge of the ATE operator, his job should be kept as simple as possible. Specifically, he should not be required or authorized to gain access to test points within an LRU nor to remove/replace printed circuit boards or modules within the LRU. Thus, specifications for the LRU TPSs include the requirement that testing of the LRU on the MSM-105 be possible as a "black box" without removing covers. The idea is to have the ATE operator run only the appropriate TPS and forward the LRU tagged with the computer diagnostics to one of the shops collocated with the ATE at the AVIM (fire-control, avionics, electronics shopvans). Repairers in those "allied shops" would perform the LRU repair (remove/replace of faulty modules isolated by the diagnostics) and return the LRU to the ATE for a quality assurance check (go/no-go chain). Faulty modules would go to the ATE at the corps AVIM for fault isolation, with repairable modules repaired at the ERF.

The problem with this concept is that about 25 percent of the TPS developed for AH-64 LRUs do not meet the original requirement prohibiting internal probing. This applies to the 41 TPSs for LRUs delivered to the

Government to date; the percentage may be higher for TPSs still under development as they include more complex LRUs associated with the target acquisition designation sight and pilot night vision sensor. Every TPS was subject to a critical design review, but when the contractor justified the need for cover removal and internal probing due to lack of access to test points, the no-probing requirement was waived to ensure fault-isolation capability. The TPSs involved provide fully guided probing, including views of component layouts on the video display terminal.

APPENDIX D

AVIM LEVEL TPS FOR AH-64 LRUS

LRU ID CODE[1]	NOMENCLATURE	TPS RUNTIME (MINUTES) FUNCTIONAL TEST	DIAGNOSTIC TEST
111	Ice Detector Control	16	6
112	Canopy Temperature Control	9	3
113	Temperature Control Sensor	2	-
115	ASE Computer	104	35
116	Lateral Accelerometer	8	-
118	Control Motion Transducer (LVDT)	4	-
119	Generator Control Unit	10	4
120	Transformer Rectifier	5	2
121	External Power Monitor	4	-
122	Anti-Collision Power Supply	6.5	3
123	Multi-Channel Dimmer	16.3	6
124	Fire Detection Amplifier	2	-
125	Speed Sequence Control	14.7	-
129	Total Gas Temperature Indicator	16.8	6
130	Oil Temperature Indicator	9.2	4
131	Engine Torque Indicator	16.8	6
132	Engine/Rotor RPM Indicator	25.3	9
133	Ng Indicator	16.9	6
134	Fuel Indicator	16.8	6
135	Selectable Digital Display	10	4
136	Refuel Indicator	7.8	-
137	Signal Data Converter	18	6
138	Electronic Attitude and Direction Indicator	30	10
139	EADI Electronic Unit	45	15
140	Horizontal Situation Indicator	15	-

[1] Identification Code in 100 series: air vehicle LRUs; 200 series: mission system LRUs.

LRU ID CODE[1]	NOMENCLATURE	TPS RUNTIME (MINUTES) FUNCTIONAL TEST	DIAGNOSTIC TEST
141	Remote Attitude Indicator	10	-
142	Warning and Master Caution Panel	4	-
143	Engine Out/Rotor Warning	5	-
144	Starter Speed Switch	2	-
145	Temperature Alarm Box	2	-
149	Dimmer Control	11.9	-
151	Oil Pressure Indicator	12	4
158	HARS Compass Control/Internal Reference Unit	108	36
160	Ice Accretion Sensor	7.5	-
161	Temperature Control Servo	4	-
163	Battery Charger	7	3
164	Rotor Blade Deicing Control Unit	15	5
165	Airspeed Indicator	not available	
166	Pilot Caution Warning/Advisory Panel	45	20
167	CPG Caution Warning/Advisory Panel	33	20
168	Audio J Box	11.5	-
169	Instantaneous Vertical Speed Indicator	not available	
170	Barometric Altimeter	not available	
171	DC Ammeter	not available	
172	AC Loadmeter	not available	
173	Turbine Speed Controller	not available	
175	Anti-Ice Panel	10	-
201	Gun Control Box	9.3	4
202	Turret Control Box	22.7	8
203	External Stores Elevation Controller	16.3	6
204	External Stores Actuator Controller	5.5	2
205	Rocket Control Panel Unit	47.2	16
207	Pylon Rocket Box	30.7	11
208	Remote Hellfire Electronics	39	13
210	Fire Control Computer	120	40
212	Air Data Electronics	73	25

[1]Identification Code in 100 series: air vehicle LRUs; 200 series: mission system LRUs.

LRU ID CODE[1]	NOMENCLATURE	TPS RUNTIME (MINUTES) FUNCTIONAL TEST	DIAGNOSTIC TEST
220	IHADSS Display Electronics Unit	27	9
221	IHADSS Integrated Helmet Unit	not available	
222	IHADSS Sensor Surveying Unit	not available	
223	IHADSS Boresight Reticle Unit	not available	
224	Fire Control Modes Panel	not available	
225	Pilot Armament Control Panel	10	-
226	CPG Armament Control Panel	21	7
227	Pilot Hellfire Control Panel	not available	
228	CPG Hellfire Control Panel	not available	
229	Data Entry Panel	19	-
230	Rounds Counter	24	-
231	Optical Relay Tube Hand Grip	not available	
232	Data Link Termination Unit	not available	
233	Multiplex Remote Terminal Unit Type IIb	not available	
234	Angle of Attack (AOA) Sensor	not available	

[1] Identification Code in 100 series: air vehicle LRUs; 200 series: mission system LRUs.

APPENDIX F

AVIATION MAINTENANCE SUPPORT AND READINESS PROBLEMS IN USAREUR

This appendix summarizes the key problems encountered by the aviation community in USAREUR. An appreciation of these problems explains our concerns about the ATE plans in support of the AH-64 and should serve to temper the optimistic assumptions by the Aviation Research and Development Command with regard to the utilization, throughput and support of the MSM-105(V)2 in the operational environment. The recently revised AH-64 fielding plan for USAREUR makes the aircraft a corps, not a division asset. This would reduce the untoward impact of introducing this aircraft in USAREUR. However, even at corps AVIM, the PM office assumptions about ATE operation and maintenance should be reassessed in view of the existing manpower, personnel and training problems plaguing Army aviation units.

The key issue is that under peacetime conditions with very limited flying hours (about 11 hours/month/AH-1) many of the units cannot meet the readiness goal of 75 percent fully mission capable, according to the Army's own data. The average achieved in V Corps in 1980/1981 was only 68 percent for the AH-1, in spite of heavy utilization of operational readiness float aircraft and an intensive management program for supply of Class IX repair parts. Causes for this shortfall are many. Key contributing factors include:

- Excessive MOS diversions for maintenance personnel, reducing their productive work time to 20 hours/week.
- Totally inadequate entry-level training, with the units not equipped to provide on-the-job training for the 85 percent of MOS tasks not taught in school.
- Poor proficiency of crew chiefs and inadequate numbers of technical inspectors contributing to a total degradation of the phased maintenance inspection system: an AH-1 spends one to three months in phased inspection vice the one to two weeks originally planned when the

periodic inspection system was replaced by the phased system in the mid-1970s.

- Poor maintenance support breeds poor pilot attitudes; at several units visited in May 1981, pilots were no longer documenting "squawks" as they felt it was not worth the effort because of lack of proficient and responsive flightline maintenance.

- Testability shortfalls of the airborne TOW missile system (M65TMS), the main weapon of the AH-1S.

- Much AVUM work evacuated to AVIM causing increasing backlogs at AVIM.

- Lack of in-theater backup capability.

To support our assessment, we summarize in Tables D-1 and D-2 the findings, conclusions and recommendations (limited to the area of maintenance) of a USAREUR Aviation Special Task Force study conducted early 1981, which may have had limited distribution outside USAREUR.

TABLE E-1. SUMMARY FINDINGS USAREUR AVIATION SPECIAL TASK FORCE

Conclusion: Lack of Capability to Reach or Sustain Realistic Readiness Goals (FMC Rate of 75 percent) for Aircraft Materiel

	Findings	Contributing Factors
(1)	Scheduled maintenance requires too much calendar time: A/C — PMI Avg. Days — Range UH-1H — 29 — (7-44) OH-58 — 42 — (9-61) AH-1S — 46 — (28-61) CH-47 — 52 — (25-70)	Excessive diversions from productive work: low productivity, lack of maintenance skills, poor supply support, cumbersome TMDE, inadequate facilities.
(2)	MTOEs are austere.	Aviation maintenance personnel must also maintain vehicles and generators. The CAB has 3 times the wheeled vehicles/power equipment of an armor bn, but only 1.5 times the operators and mechanics. Parity would require adding 66 personnel.
(3)	MOS diversion reduce productive hours to 20 hours/week for aircraft maintenance.	Diversions include mandatory training, motor pool, security and troop diversions. USAF maintenance personnel devote 35 hours of a 42-hour duty week to aircraft maintenance.
(4)	Maintenance personnel are inadequately trained.	TRADOC objective is to train individuals to 30 percent of MOS critical tasks but AIT graduates can only perform 10 percent of those tasks effectively. Lateral entrants into mid-level supervisor billets from other career fields get only entry-level training.
(5)	Facilities are as inadequate as in most other commodity areas but this has a greater adverse impact on aircraft readiness due to complexity and frequency of aircraft maintenance.	Electrical power in most hangars inadequate to support current aircraft ground test equipment and unacceptable for AH-1S(FM) and UH-60. Lighting is inadequate in 50 percent of the hangars. Heating is inadequate, reducing productivity in winter time. Many hangars lack overhead hoist.
(6)	TMDE repair support remains intolerable, although calibration support has improved since DARCOM takeover.	Obsolete TMDE: inadequate quantities of TMDE; inadequate staffing of USATESAE; lack of TMDE repair parts; lack of command emphasis in units.
(7)	Lack of a backup maintenance capability in-theater will limit wartime surge and sustainment capabilities.	Organic AVIM capability in USAREUR lacks depth and has no quick access to depots. This is evidenced by record levels of "hangar queens" (A/C down for 90 days or longer). This situation will get worse with the projected non-availability from CONUS of new/rebuilt Lycoming engines due to M-1 priority and quality control problems at the plant.
(8)	Aviation material management is inadequate from battalion through theater level.	Management resources at echelons above company are practically non-existent. The CAB and DMMC have one E-7 each authorized. Corps MMC are totally understaffed. HQ USAREUR, ODCSLOG, has only 1 major part time for this function.

TABLE E-2. SUMMARY RECOMMENDATIONS USAREUR AVIATION SPECIAL TASK FORCE

Problems Area/Finding

- AIT graduates perform 10 percent of MOS critical tasks.

- First reenlistment entries from other CMFs into CMF 67 are high, yet receive only skill level 10 training (in FY79 50 percent of personnel in year group 4 came from other CMFs).

- Self-paced training approach is ineffective for sophisticated equipment.

- Training evaluation through SQT is misleading by requiring mechanics to memorize technical manual content which is in conflict with SOP (90 percent failed CMF 67 SQT overall, but 90 percent passed hands-on component).

- AVIM units have a lower MTOE fill in MOS 67N (UH-1 repairman) and 67Y (AH-1S repairman) than do AVUM units. (MOS 67N: AVIM has 79 percent vs. AVUM 98 percent; MOS 67Y: AVIM has 77 percent vs. AVUM 93 percent).

- 68 series MOS is low density in AVUM units by MTOE authorization: average density is two in grades E4/below for 68B,D,F and H (A/C power plant, power train, electrician and pneudraulics repairer, respectively), with no E5/above authorized. The 68K supervisor billet was either not filled or filled by an individual unqualified to provide OJT. As a result, most of the work involved, though AVUM level, is done by AVIM; this is the main contributor to AVIM work backlog.

- MTOE of the air troops in the ACR does not provide qualified supervisory personnel (WO) for AH-1S armament system (in contrast to the MTOE for CAB).

- Based on programmed flying hours and observed PMI times, 50 percent of the unit maintenance programs cannot support a peacetime FMC rate of 75 percent. Root causes include: MOS diversions: skill deficiencies; and poor execution of the PMI concept which requires continuous inspections to be successful.

- Units achieving the shortest PMI duration or highest FMC rates showed command emphasis on balancing operational requirements vs. maintenance capabilities; sustainment of orderly maintenance flow vice short term FMC objectives; and crew chiefs participating in PMI.

- MTOE authorizations for aviation materiel management are inadequate in all echelons from battalion through HQ USAREUR.

- Maintenance capability at the Corps AVIM units is saturated as evidenced by the following backlog data as of February 1981:
  - 22 hangar queens (=A/C NMC is excess of 90 days) with average days NMC of 172 days.
  - 14 aircraft NMC from 60-80 days, of which 13 awaiting depot level repair or TSARCOM disposition instructions
  - this backlog resulted in spite of backup maintenance support from 70th Trans Bn (7100 manhours in 6 months).

- Management of TOW Missile System (TMS) LRUs is inefficient: unit TAT is 3 to 4 weeks, while actual repair TAT at PIMRA takes 2 to 3 days. This affects DX stockage required at Corps AVIM.

Recommendations

(1) Train all skill level 10 MOS critical tasks in AIT. Require demonstrated proficiency in 100 percent of MOS critical tasks as a condition for MOS award.

(LMI Comment: This could triple the AIT course length if training methodology remained constant).

(2) Modify training program for E-5/above reenlisting from other career fields to prepare individuals for supervisory (skill level 20) duties.

(3) Modify written component requirements of SQT to permit "open book" examination.

(4) Cross level MOSs within the combat Aviation Battalions and the Corps AVIM Battalions.

(5) Rotate personnel in MOS 68B,D,F and H to AVIM units to receive supervised OJT.

(6) Modify the MTOE for the ACR to show a requirement for three 100EE armament warrants per air troop as provided in the CAB MTOE.

(7) Reinstate the aircraft armament officers course directed at COBRA/TOW.

(8) Increase manhours available for aircraft maintenance by reducing competing requirements:
- civilianize those that can be (e.g., security, driver details)
- increase MTOE authorization for motor maintenance
- schedule mandatory training outside normal duty hours.

(9) Require technical inspection of aircraft 25 flight hours prior to scheduled PMI to identify maintenance and parts requirements.

(10) Expand the USAREUR Aviation Orientation Course for commanders and maintenance officers with a block of instruction on effective maintenance management.

(11) Enforce utilization of assigned crew chiefs in PMI.

(12) Develop a more realistic measure of aviation unit readiness based on maintenance flows vice pure FMC rates.

(13) Submit MTOE change requests for divisional CABs and MMCs; 300th MMC (VII Corps) to the level approved for 19th MMC (V Corps); 200th TAMMC; and HQ USAREUR, ODCSLOG.

(14) Develop backup depot-level capability in-theater for airframe and component repairs through contracts with German aircraft manufacturers and U.S. corporations.

(15) Provide the Corps AVIM battalions TDA augmentation with local hire maintenance personnel.

(16) Institute intensive management program for TMS LRUs to reduce nonproductive processing and transportation times, monitor the inventory of LRUs and balance distribution between Corps as needed.

TABLE E-2. SUMMARY RECOMMENDATIONS USAREUR AVIATION SPECIAL TASK FORCE (Continued)

- TMS troubleshooting problems are evidenced by high NEOF rates of LRUs evacuated to PIMRA (27 percent overall for past 12 months).

- Replacement of ORF aircraft does not keep pace with attrition: theater is currently short 13 UH-1 and 4 OH-58 ORF assets.

- Repair parts availability is a major detractor of readiness but cannot be substantiated by 2406 or 1352 reports because a total work stoppage must occur before aircraft can be reported NMCS. OST for NORS requisitions is 28-35 days but seldom causes total work stoppage given PMI duration. Extensive cannibalization and parts borrowing between units, mask supply problems. PLL clerks are inexperienced and supply management is weak. Due to cost of aviation parts, a greater portion of aviation requisitions are kicked out by DLOGS and SAILS for manual processing. The number of items selected for AIMI is increasing (= in short supply) but a high percentage cannot be ordered until aircraft is NORS.

- Facilities are deficient and impact adversely on readiness. Hangars have been diverted to other purposes. Most airfields do not have sufficient hardstand parking. 70 percent of facilities have inadequate electrical power for current aircraft, while an additional 17 percent will become inadequate with fielding of AH-1S (MC) and UH-60. As a result, tactical generators must be used causing additional maintenance. Over 50 percent of hangars have inadequate lighting, requiring use of portable floodlights powered by tactical generators. Over 50 percent of hangars have inadequate heating. 40 percent of hangars have no overhead hoist, with an additional 20 percent having inoperative hoists so that lift requirements must be met by borrowing a wrecker.

- AR 95-33 is ambiguous with respect to whether aircraft is FMC or PMC.

- AR 220-1 includes the UH-1 as an equipment pacing item in the attack troop of the ACR (MTOE 17-387). Due to its low density (the unit is authorized 21 AH-1S, 12 OH-58 and 3 UH-1), the impact of the UH-1 on readiness computation is disproportionate to its impact on the unit's primary mission.

- USAREUR has no inspection program to systematically evaluate unit aviation maintenance and supply management in contrast to other commodity areas which periodically receive logistics inspections (MAIT, CLAIT).

- Inadequate TMDE and maintenance support for TMDE adversely affects readiness. Majority of aviation TMDE is 1950s era so that repair parts are difficult to get. The October 1979 DARCOM TMDE support mission was grossly under resourced resulting in excessive turnaround for TMDE repair.

(17) PIMRA provide NEOF feedback data to AVIMs and DARCOM LAOs to identify troubleshooting problems and corrective action requirements.

(18) Establish stringent USAREUR policy for management and utilization of ORF.

(19) Articulate to HQDA need to fill ORF shortages to maintain ORF assets at 10 percent of TOE authorizations.

(20) Coordinate with TSARCOM more timely procedures for retrograde/repair of damaged aircraft.

(21) Improve training of PLL clerks and maintence supervisors.

(22) Require DMMCs to conduct quarterly supply management reviews with supported units.

(23) Require COSCOM MMCs to conduct quarterly reviews with supported DMMCs.

(24) Submit change recommendation for AR 95-33 to identify statistically cannibalization actions with reduced supply responsiveness.

(25) Consider changing the DLOGS and SAILS criteria for aviation Class IX manual management procedures.

(26) Articulate to HQDA the need to reduce the number of items under AIMI management constraints.

(27) Develop theater capability to monitor Class IX stocks among ASL and GSSB stocks; develop procedures to move parts between ASLs and GSSBs.

(28) Use MCA funds to build non-aviation facilities to release the converted facilities back to aircraft maintenance.

(29) Construct needed helicopter parking pads.

(30) Initiate actions to upgrade power supplies in all aircraft maintenance facilities.

(31) Upgrade facilities to improve lighting, heating and lift capabilities as needed.

(32) Develop specific USAREUR criteria for definition of FMC and PMC by type aircraft/primary mission and submit these criteria for next revision of AR 95-33.

(33) Develop change recommendation to AR-220-1 deleting the UH-1 as an equipment pacing item in MTOE 17-387.

(34) Restructure the Aviation Operational Readiness and Safety Evaluation (AORSE) system to focus more on aviation materiel management issues/problems affecting unit readiness.

(35) Units must appoint and educate TMDE calibration/repair coordinators.

(36) A new test set (AN/GRM114) being fielded for ground FM radios could replace six pieces of TMDE most frequently used in avionics maintenance and should also be authorized to aviation maintenance units.

(37) USATESAE to consider increasing the use of mobile calibration/repair teams instead of the current fixed base operations.

(38) Articulate to HQDA the necessity to expedite the electronic TMDE modernization program.

GLOSSARY OF TERMS FOR TABLES E-1 AND E-2

A/C	-	aircraft
ACR	-	armored cavalry regiment
AIMI	-	aircraft intensive-management item
AIT	-	advanced individual training
AORSE	-	Aviation Operational Readiness and Safety Evaluation
ASL	-	authorized stockage list
AVIM	-	aviation intermediate maintenance
AVUM	-	aviation unit maintenance
CAB	-	combat aviation battalion
CLAIT	-	Command Logistics Assistance and Inspection Team
CMF	-	career management field
CONUS	-	continental United States
COSCOM	-	corps support command
DARCOM	-	Materiel Development and Readiness Command
DLOGS	-	direct logistics system
DMMC	-	Division Materiel Management Center
DX	-	direct exchange
FMC	-	fully mission capable
GSSB	-	general support supply base
HQ	-	headquarters
HQDA	-	Headquarters, Department of the Army
LAO	-	Logistics Assistance Office
LRU	-	line-replaceable unit
MAIT	-	Maintenance Assistance and Inspection Team

MC	-	mission capable
MCA	-	military construction, Army
MMC	-	materiel management center
MOS	-	military occupational specialty
MTOE	-	modified table of organization and equipment
NEOF	-	no evidence of failure
NMC	-	not mission capable
NMCS	-	not mission capable, supply
NORS	-	not operational ready, supply
ODCSLOG	-	Office of the Deputy Chief of Staff for Logistics
OJT	-	on-the-job training
ORF	-	operational readiness float
OST	-	order-and-ship time
PIMRA	-	Pirmasens Missile Repair Activity
PLL	-	prescribed load list
PMC	-	partially mission capable
PMI	-	phased maintenance inspection
SAILS	-	Standard Army Intermediate Logistics System
SOP	-	standard operating procedure
SQT	-	skill qualification test
TAMMC	-	Theater Army Materiel Management Center
TAT	-	turnaround time
TDA	-	table of distribution and allowances
TMDE	-	test, measurement and diagnostic equipment
TMS	-	TOW Missile System
TOE	-	table of organization and equipment
TOW	-	tube-launched, optically-tracked, wire-guided

TRADOC	-	Training and Doctrine Command
TSARCOM	-	Troop Support and Aviation Materiel Readiness Command
USAREUR	-	U. S. Army Europe
USATESAE	-	United States Army Test Equipment Support Activity, Europe
WO	-	warrant officer

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The Army's new advanced helicopter, AH-64 relies on automatic test equipment (ATE) at aviation intermediate maintenance (AVIM) units for testing and diagnosis of faulty components removed from the aircraft. The Army is planning to provide one ATE station to each division and corps aviation brigade AVIM unit that supports the AH-64. Our independent analysis indicates that one ATE per AVIM unit may be sufficient only if the mean time between removal of AH-64 line replaceable units is 6 to 8 flying hours or greater, a figure

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that, though perhaps achievable, is twice that demonstrated so far in operational testing.

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